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A Summary of Current Program 7/1/67

and Preliminary Report of Progress

for 7/1/66 to 6/30/67

ENTOMOLOGY RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

Section A

This progress report is primarily a tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between July 1, 1966, and June 30, 1967. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE

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INTRODUCTION

Research in the Entomology Research Division is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugarbeets, and ornamental crops; turf, pasture and range plants; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock. Basic research is conducted in insect pathology, physiology, biochemistry, nutrition, metabolism and genetics.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many kinds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at almost 7 billion dollars annually. In addition, approximately 24 million dollars of public funds are expended annually in cooperative insect eradication and control programs.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological, and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits to provide specific methods of control

for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction, sex pheromones and electromagnetic, sonic and ultrasonic energy. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has 440 professional scientists at 64 field locations in the United States, 9 in foreign countries, and one in the Virgin Islands. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Departments of Defense, State, Interior, and Health, Education and Welfare, Atomic Energy Commission, World Health Organization, and the International Atomic Energy Agency.

The Division also sponsors 154 domestic research projects through grants, contracts, and cooperative agreements negotiated with State experiment stations, universities, boards of health, and independent laboratories throughout the United States.

The Division also sponsors 68 research projects in 14 foreign countries financed under the Public Law 480 program for utilizing foreign currencies received in payment for excess agricultural products from the United States. Research is conducted under agreements with the Agency for International Development in Nigeria, Uganda, and Rhodesia in Africa, Karaj, Iran and New Delhi, India.

A broad analysis of the Division's intramural research by different approaches to insect control shows that about 21 percent of the current effort is on the conventional chemical approach to insect control; 13

percent on biological control (parasites, predators, and pathogens); 7 percent on plant resistance to insects; 22 percent on the sterility and other new approaches to insect control such as natural attractants; and 37 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases.

The following are examples of recent outstanding developments in entomological research in this Division and in the State Experiment Stations. The latter were supplied by the Cooperative State Research Service.

ENTOMOLOGY RESEARCH DIVISION, ARS

Sex attractants in insects. Progress in research on sex attractants of a number of species of important pest insects continues. Two procedures have been developed for synthesizing the sex pheromone produced by female fall armyworm moths. One of these methods should be adaptable to commercial production of the pheromone. In laboratory bioassay tests this material was shown to stimulate also male gypsy moths.

Two synthetic analogs of propylure, the pink bollworm sex attractant, have been found sexually attractive to male fall armyworm moths. Several homologs of propylure recently synthesized show attraction for male pink bollworm moths.

The sex attractant produced by female codling moths has been isolated in pure form. Investigation of its molecular structure is in progress. A total of 300,000 female moths were used to obtain 51 micrograms of the pure attractant.

A procedure developed by the Pesticide Chemicals Research Branch was used to produce commercially 500 grams of the synthetic cabbage looper sex attractant. The product was highly attractive to male cabbage looper moths in the field.

Attractants for yellow jackets. Certain esters of alpha beta-unsaturated acids were found the most effective among more than 100 compounds tested as attractants for yellow jackets. They were highly specific, catching no beneficial insects such as honey bees. Radiophosphorus-labeled yellow jackets were collected as far as 3,000 feet from their nest with one of these, 2,4-hexadienyl butyrate. This lure may be useful in protecting outdoor working and recreational areas from yellow jackets.

Insect hormones. A naturally occurring compound with strong juvenile hormone activity for insects in the family Pyrrhocoridae was isolated and identified from wood of the balsam fir tree (Abies balsamea) and named juvabione. This compound readily penetrates the insect cuticle, interferes with insect development and blocks metamorphosis in treated insects. The family Pyrrhocoridae contains several pest species, such as the cotton stainers. The high biological activity and specificity of this compound indicates the possibility of tailoring compounds to affect only insect pests without harming beneficial insects.

Diapause has been successfully terminated in several adult insects including the alfalfa weevil and the cereal leaf beetle. Topical treatment of diapausing beetles with the potent synthetic juvenile-gonadotropic hormone 10,11-epoxyfarnesenic acid methyl ester induced previously diapausing beetles to begin feeding, mating, and reproducing within approximately a week after treatment. Since diapause is a protective mechanism which allows the insect to survive inclement periods of heat, cold, and drought, interruption of this protective state exposes the insect to a hostile environment at a time when it is unequipped for survival.

Insect sterilization. Irradiation sterilized males of the southern house mosquito but reduced their competitiveness with normal males. Males sterilized with the chemosterilant, apholate, were equally competitive with normal males in mating with untreated females.

Eighty of 1,004 chemicals screened for chemosterilant activity caused complete sterility in adult house flies. Permitting emerging flies to crawl through chemosterilant-treated styrofoam pieces produced high sterility.

Biological control. Twenty-one species of parasites and predators of eight kinds of pest insects were collected in Europe and introduced into the United States. Eighteen species of parasites and predators of 12 kinds of pest insects were received from P.L. 480 projects in India and Pakistan and 10 species from other sources. These totalled approximately 45,000 specimens in 141 shipments. They are being screened and tested and some propagated before transhipment to Division or cooperating State field stations for further propagation and/or release.

Two releases of large numbers of larvae of the green lacewing, a predator on bollworm eggs and larvae, controlled cotton bollworms as effectively as the best currently available insecticide in a test. Research to develop this procedure for practical adoption is continuing.

STATE EXPERIMENT STATIONS

Sex attractants to improve insect control. Research of the California station has shown that there is a sex attractant for the California five-spined ips beetle, Ips confusus, in the frass material produced by the male boring in freshly cut pine. This material is attractive to both males and females and is present on and throughout the dense fecal pellets. A joint investigation between the California station and Stanford Research Institute has shown that there is more than one material that enters into this attractive pheromone.

The Alabama station in research on the sex attractants of the female cabbage looper moth, has isolated and identified an attractive chemical - CIS-7-dodecen-1-d acetate. The chemical structure of the attractant was verified by synthesis of the compound which was as attractive as the natural product.

The Kansas station, in its research on the angoumois grain moth, has found that by simple extraction of female moths, a material can be obtained that attracts males and stimulates their mating behavior. In each of these three instances, the workers at the State stations have demonstrated that there are natural attractants that may be useful in control.

Mosquito oviposition lure. During a period of 6 years, the Delaware station was successful in the isolation of a chemical substance possessing a high degree of attractiveness to ovipositing female mosquitoes, Culex Salinarius, Coq. This attractant material is of protein origin, apparently derived in the environment from decaying plant tissues. In field tests, water suspension containing this proteinaceous trichloroacetic acid extract actively attracted more ovipositing female mosquitoes than did the raw infusion, and significantly more than the native habitat or tap water. Gravid females were shown to be definitely oriented towards the attractant.

Insect pests in outdoor recreation areas. The Georgia station has been surveying various representative recreational areas in different parts of the State to determine the insect pests that are annoying or injurious in them. The pests in picnic areas were found to consist mostly of non-biting flies although eye gnats were important in the coastal plains area. Yellow jackets and deer flies were particularly annoying to campers and fishermen. Of the 20 common foods used for bait to study the daylight activities of these pests, ground beef and bananas were preferred by Colliphorid flies while yellow jackets preferred grapes and fish. The peak of activity of these pests occurred from 1 to 3 p.m. Light traps baited with CO^2 were used to study the daily activity of biting flies. Catches recorded at hourly intervals indicated that black flies were diurnal with slight peaks in mid-morning and mid-afternoon. Mosquito activity was essentially constant during the night, tapering off at sunrise. Exploratory studies with poison baits to control yellow jacket colonies resulted in partial control with sodium arsenate in macerated grapes. With the development of recreation as a more important activity in rural areas, the importance of insect pests and their control in these areas has greatly increased.

Imported parasite controls California red scale. The parasite, Aphytis melinus, was introduced into California from Pakistan. Studies by the California station over the last five years have shown that in many citrus areas of California, particularly near the coast, the parasite has almost completely replaced ineffective parasites of other species and now provides a high and satisfactory degree of red scale control without the use of pesticides.

Parasite controls Rhodesgrass scale in South Texas. Texas Agricultural Experiment Station entomologists have known the effectiveness of using the wingless wasp, Neodusmetia sangwani, to parasitize Rhodesgrass scale for some time. Now with the aid of high speed distribution, the concept could easily be employed to treat the entire area infested with scale. Large areas have been seeded with grass sprigs infested with scale, which in turn, are parasitized by the wasp. The grass sprigs are dispersed by dropping

them in frozen food cartons from low-flying aircraft as in the screw-worm eradication program. The parasites emerge from the grass sprigs and attack the scale in the area where they are dropped. They spread over large areas. Experimental drops have shown remarkable reduction in scale populations and substantial increases in forage yields. The research is supported by a grant from the Entomology Research Division.

Drift of insecticides during application. The California station has investigated this problem and found that wind velocity and temperature conditions are of major importance in drift. In their studies, they developed figures showing how far drift might extend under "good" weather conditions. Good weather conditions require wind velocities of 4 to 7 miles per hour or less and normal temperature conditions in the air above the ground. Applications under strong temperature inversion conditions or in windy turbulent weather when the wind velocity is from 8 to 10 miles per hour will increase residue deposits from 3 to 10 times, depending on the distance down wind, and extend the deposits for a farther distance down wind. Two other important factors governing the amount of residue resulting from drift were the rate applied per acre and the residual half life of the insecticide. In spray tests with five commonly used insecticides and two miticides, the California station found that significant residues did not normally occur down wind for the following distances and time intervals: zero days after application - 500 to 2900 feet; 6 days - 250 to 1200 feet; and 12 days - 100 to 600 feet.

Washing removes pesticide residues. An intensive study of the effectiveness of washing fruits and vegetables with water and various detergents for the removal of certain surface residues, is in progress at the New York State Agricultural Experiment Station. During the past year preliminary studies were undertaken for the removal of captan, parathion, and methoxychlor from Hudson cherries, DDT from applies, and endrin from cole crops. In all cases, significant reductions in the surface residues could be accomplished without alteration of keeping quality of the produce.

AREA NO. 1. VEGETABLE INSECTS

Problem. More effective, economical, and less objectionable methods of controlling insect and mite pests of vegetables in the field without leaving undesirable residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, or adversely affecting beneficial insects, are the major objectives of this research. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating animal products by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into non-target areas may also cause problems. A number of vegetable insects have developed resistance to certain insecticides. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects and mites; bioenvironmental and cultural methods; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; evaluation of insecticide application equipment; and the practical integration of non-chemical and chemical methods in area control of vegetable insect and mite pest populations. Additional emphasis is being placed on research to develop vegetable crops resistant to insects and to determine the factors responsible for resistance when found. Research is needed on insect vectors of vegetable diseases and the role they play in the dissemination of viruses. The heavy losses caused by viruses transmitted by insects to a variety of vegetable crops emphasizes the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz., Riverside, Calif., Tifton, Ga., Twin Falls, Idaho, Lafayette, Ind., Beltsville, Md., Wooster, Ohio, Forest Grove, Oreg., Charleston, S.C., and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work in in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Research is being conducted in Indiana and Washington under a research grant to the Indiana Agricultural Experiment Station and by cooperative agreement with Walla Walla State College, respectively.

Work in Karaj, Iran, and New Delhi, India, on insects affecting vegetable legumes is supported with funds supplied by the Agency for International Development (AID) under the grain legume project in cooperation with the Crops Research Division, the Soil and Water Conservation Research Division, Karaj Agricultural College, the Iran Ministry of Agriculture, the Iran Plan Organization, Pahlavi University in Shiraz, Iran, the Indian Council for Agricultural Research, and the Indian Agricultural Research Institute.

The Federal scientific effort devoted to research in this area totals 27.1 scientific man-years. Of this number 1.7 is devoted to basic biology, physiology, and nutrition; 2.9 to insecticidal and cultural control; 3.2 to insecticide residue determination; 6.4 to biological control; 4.0 to insect sterility, attractants, and other new approaches to control; 1.8 to evaluation of equipment for insect detection and control; 5.2 to varietal evaluation for insect resistance; 0.4 to insect vectors of diseases; and 1.5 to program leadership.

In addition Federal support of research in this area under contracts and grants provides 0.8 man-years. Of this total 0.2 is devoted to biological control and 0.6 to insect sterility, attractants, and other new approaches to control.

Two projects have recently been initiated under PL 480 research grants in Israel. These include studies on periodic acquisition of tomato yellow leafcurl virus by its vector the tomato whitefly (A10-ENT-21) and on development of methods for control of the Baluchistan melon fly (A10-ENT-24). Other PL 480 research projects underway include research in India on Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases (A7-ENT-22) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (A7-ENT-44) and in Israel on factors influencing variations in resistance of insects to insecticides (A10-ENT-13).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 47.5 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Southern Potato Wireworm. Conoderus falli adults constituted 99% of the elaterids caught in a 15-watt blacklight trap operated throughout 1966 in a vegetable growing area near Charleston, S.C. Eighty-five percent of the elaterid larvae in samples of cultivated soil in the area during October and November were southern potato wireworm. An average of 3.0 elaterid larvae per square foot, to 6-inch depth, were found. Of 223 potato lots inspected, 11.2% showed 1.5 to 2.9% by weight wireworm "damaged" tubers.

2. Cucumber Beetle Rearing. At Charleston, S.C., large numbers of banded cucumber beetles, spotted cucumber beetles, and striped cucumber beetles were reared in the laboratory with relatively simple equipment and at a reasonable cost.

3. Cabbage Looper. At Charleston, S.C., cabbage looper larvae were reared to pupation on a standard collard powder diet or the standard diet diluted by doubling the distilled water content. Pupae from larvae reared on the standard diet were heavier than the pupae from larvae reared on the diluted diet.

At Riverside, Calif., calcium and sodium ascorbate were satisfactory substitutes for ascorbic acid in cabbage looper larvae diets. Blending of cabbage looper larval diet after preparation in the steam kettle was found to be a necessary step in the preparation of the medium. Studies indicate that blending the wheat germ dietary component before adding it to the kettle and subsequent normal mixing in medium preparation may be an adequate substitute procedure.

4. Lygus. Weekly sweep-net surveys for lygus from August through September 1966 at Riverside, Calif., indicated highest lygus adult and nymph populations of 1.10 and 1.06 per sweep on August 17 and 9, 1966, respectively. Lowest populations were .33 adults and .13 nymphs per sweep on September 8 and August 23, respectively.

5. Pepper Weevil. Also at Riverside higher pepper weevil populations were found during mid-September to late November in pepper fields where second fruit set and blossoms were available compared to populations in fields with plants that did not fruit a second time.

Pepper weevils have been successfully reared on a modified boll weevil diet and also on a modified cabbage looper diet. More nonviable eggs were obtained from weevils reared on the looper diet, but adults were larger and emerged at least two days earlier than those reared on the boll weevil diet. Reducing the mold inhibitor content of the looper diet resulted in higher and earlier emergence and increased egg hatch. Five, four, and two generations, respectively, of weevils have been reared on boll weevil diet, cabbage looper diet, and cabbage looper diet with reduced amounts of mold inhibitors. Emergence ranged from 48 to 64%, 45 to 56%, and 60 to 69%, respectively.

6. Flea Beetle. At Beltsville, Md., tobacco flea beetle larvae in all stages of development tunneled into tomato seedling roots and the hypocotyls collapsed, followed by plant prostration. The symptoms are strikingly similar to "damping off" and may be erroneously ascribed to infection by Rhizoctonia, Pythium, or other soil fungi.

Several generations of tobacco flea beetles have been successfully reared on subirrigated potato plants grown in a fertilized peat-vermiculite mixture at 80° F, 70-80% relative humidity, and 16-hour photoperiod. Adults oviposit

on moist cheesecloth. The eggs are collected and surface sterilized in chlorinated water. Behavior and development of larvae may be easily studied by transferring the young larvae onto the roots of tomato seedlings growing in transparent Grow Pouches. Under these conditions egg to adult development is completed in 22-26 days as follows: Egg, 4-5 days; larval stage, 13-15 days; and pupal stage, 5-6 days.

7. Empoasca. At Delhi, India (A7-ENT-22) orientation studies showed that Empoasca devastans has greater preference for the hosts Gossypium hirsutum, G. herbaceum, and Solanum melongena than for G. arboreum, Ricinus communis, and S. tuberosum. Empoasca kerri motti had greatest preference for R. communis. Feeding studies showed that E. kerri motti larval weight gain as well as growth index was highest when this leafhopper was reared on R. communis and S. tuberosum. No difference in larval weight gain nor growth index was observed when E. devastans was reared on these hosts.

8. Corn Earworm. At Tifton, Ga., the casein-wheat germ diet has been replaced with a less expensive pinto bean diet for corn earworm rearing. The bean diet has been satisfactorily modified to shorten length of time required for pupation and to obtain a more uniform rate of pupation. Eggs are surface sterilized chemically, dried, removed, and then added directly to the diet, using a small hand shaker. Insects are stored until pupation, then moved to a large room for emergence. Moths are sexed as they are collected from the walls and ceiling twice daily, using hair-dryer collectors. Agricultural engineers at Tifton, Ga., in cooperation with entomologists, have developed a machine for collecting the pupae from individual cups automatically. Additional modifications are needed to make this machine fully satisfactory.

At Tifton, a detailed study of the corn earworms' antennae has revealed a minimum of 14 separate distinct types of sensors. These sensors have been plotted both with respect to the number present and to their physical configuration on the antennae of 4 different species of Noctuidae and 1 species of Pyralidae. Accurate plots of the placements of the various sensillae and their length in relation to the position they occupy on the antennae are necessary in order to define the array configurations of these antennae. Electrophysiological work has shown that the scape and pedicel dome sensor, of the noctuid and saturnid antennae responds to visible radiation.

At Tifton data for the oxygen consumption of the larval and pupal stages of the corn earworm were obtained. On the basis of microliters per milligram per hour the pupae exhibit a typical U-shaped curve, while larval curve is inversely related to total weight. Also, the corpora alata, corpora cardiaca, and the prothoracic glands have been located and described.

B. Insecticidal and Cultural Control

1. Western Bean Cutworm. At Twin Falls, Idaho, trichlorfon in baits or as sprays or dusts, and azinphosmethyl and Bay 39007 as sprays were less effective than DDT for western bean cutworm control. However, 5% trichlorfon dust gave good control.

2. Beet Leafhopper. At Twin Falls the crested wheatgrass reseeding program and a dry season reduced Russian-thistle stands and resulted in one of the lowest fall leafhopper populations ever recorded. As a result, little damage was caused by the beet leafhopper in the Magic Valley of Idaho during the spring of 1967.

3. Cabbage Looper. At Charleston, S.C., 54 chemicals were laboratory bioassayed for toxicity to cabbage looper larvae. Three showed a high order of toxicity. Six other candidate materials showed sufficient promise to justify further trials. Weekly applications of nine were superior for looper control on field-grown fall cabbage than the currently recommended parathion and naled. Five candidate materials gave better looper control on spring cabbage than the currently recommended mevinphos.

4. Southern Potato Wireworm. Seventeen chemicals were compared in laboratory tests at Charleston, S.C., for toxicity to southern potato wireworm larvae. Bay 77488 and 78182 were most toxic. Dursban (2 and 4 lb/acre), S 6538 (2 lb/acre), and Bay 77488 (2 lb/acre) sprays gave 95 to 100% reductions of southern potato wireworm larvae in fall field tests.

5. Mexican Bean Beetle. At Beltsville, Md., leaf samples from bean plots at various times after treatment with granular dimethoate, UC 21149, phorate, or NIA 10242 were fed to Mexican bean beetle larvae, each at the rate of 1 and 2 lb/acre. Toxicity of all 5 materials decreased in the order given and in each case more rapidly at 1- than at 2-pound dosages. Adult bean beetles fed on harvested pods from all plots were unaffected.

6. Drosophila. In tomato field plots at Beltsville, Md., baited gallon jars dipped in 1% aqueous suspension of lindane WP and covered with lindane-treated tomato hampers and distributed at the rate of 134 jars/acre gave 85% Drosophila control. Sixty-seven and 34 jars/acre gave 64 and 46% control, respectively. The bait was vermiculite soaked with 20% granulated sugar, 6% active dry yeast, 5% glycerine, 2% apple cider vinegar, and water. Fresh jars and baskets were distributed in the plots at weekly intervals during the harvest period.

7. Corn Earworm. Low volume formulations for control of corn earworm on sweet corn found as effective as 2 lb/acre DDT EC standard were endosulfan-malathion at 0.57, endosulfan at 0.72, malathion-DDT mixture at 0.4 and 1.6 pounds, respectively, and SD-8447 at 1 lb/acre.

Results of laboratory tests using excised corn leaf segments as a substratum indicated that a water extract of corn kernels as an attractant mixed with the insecticide SD 8447, used at the rate of 0.5 ounce of active ingredient per 25 gallons of water, increased earworm larval mortality approximately 30% above that obtained with SD 8447 check. A water extract of silks increased mortality approximately 20%, while a water extract of leaves gave no apparent effect.

8. Bean Insects. At Yakima, Wash., UC 21149 was the most effective of 4 systemic insecticides for control of lygus bugs, leafhoppers, and thrips and sidedress applications were more effective than broadcast applications.

C. Insecticide Residue Determination

1. Greenhouse Insecticide Applications. At Beltsville, Md., 10% dichlorvos aerosol at .1 lb active ingredient per 5,000 ft^3 to greenhouse cucumbers, tomatoes, and Bibb lettuce gave residues in 2-hr samples of 0.01, .02, and .24 ppm, respectively. Residues in samples 1 day after treatment were less than .01 ppm.

In parallel tests with 10% sulfotepp aerosols, 2-hr samples showed residues of 0.12 ppm and 0.20 ppm from tomatoes and Bibb lettuce, respectively, and residues of 0.02 ppm in both products one day after treatment.

Azinphosmethyl (50% WP) applied to cucumbers at 0.5 pound active ingredient per 100 gal water gave residues of 0.05, 0.01, and less than 0.01 ppm in 1 hr, 1 day, and 8 days after treatment. At 1.0 lb/100 gal, residues were 0.03 ppm after 1 hr and .02 ppm after 8 days. Tomatoes similarly treated with azinphosmethyl at 0.25, 0.5, and 1.0 lb/100 gal showed 1-hr residues from all treatment levels of 0.06 ppm and less than 0.01 ppm after 8 days.

2. Azinphosmethyl Drift from Airplane Application. At Beltsville, Md., azinphosmethyl at 1/2-lb/acre was applied by airplane from an altitude of 8 ft as a low-volume spray containing 22.5% of the technical compound or as an aqueous emulsion containing 2 ounces per gallon, and from an altitude of 30 ft as the low-volume spray. Maximum deposits of azinphosmethyl on glass filter paper discs attached to aluminum plates and petri dishes placed at intervals in and near the treated areas were found approximately on the line of application from the 8-ft level but at a distance of about 80 ft from this line for the application from the 30-ft level. Deposits extended to a considerably greater distance when applied from the 30-ft level than when applied from the 8-ft level. Azinphosmethyl was found in air samples at a distance of 2,000 ft from the spray area.

3. Persistence of Azodrin in Sweet Corn. At Tifton, Ga., plots of sweet corn were treated with aqueous solutions of Azodrin at rates of 0.56, 1.12, and 2.24 kg/hectare. With the highest level of treatment, initial residues in the stalks and leaves averaged 91.6 ppm, which declined to 1.09 ppm 16 days later; initial residues in the ears averaged 0.10 ppm and declined to less than 0.005 ppm within 8 days; initial deposits on the husks and silks averaged 67.0 ppm and declined to 0.13 ppm 16 days later.

4. DDT and Malathion Residues in Corn After Low-Volume Applications. Also at Tifton, plots of sweet corn were sampled after each of 5 low-volume applications of DDT (0.56 kg/hectare) and malathion (1.68 kg/hectare) at 3-day intervals and also at harvest. The highest levels found at any time were 16.5 ppm DDT and 31.8 ppm malathion after the second treatment. At

harvest (7 days after last treatment), the residues averaged 6.23 ppm DDT and 0.82 ppm malathion.

5. Corn Earworm. At Tifton, Ga., gas chromatographic methods were developed for analyzing Azodrin and Bidrin. The methods employ the Melpar flame photometric detector with the 526 mμ interference filter. Samples are blended with chloroform and the raw extracts are analyzed with no further cleanup necessary. Recoveries from sweet corn spiked with Azodrin (0.05 to 5.00 ppm) prior to extraction were better than 95%.

Residues of DDT-malathion applied at 0.4 and 1.6 lb/acre, respectively, were determined on corn plants after each of 5 application dates and at harvesttime. After each of the 5 applications, residues ranged from 4 to 25 ppm. Residues averaged 6.25 ppm DDT and 0.82 ppm malathion at harvesttime on the plants.

D. Biological Control

1. Fall Armyworm. At West Lafayette, Ind., quantitative studies with the fall armyworm nuclear polyhedrosis virus indicate an LD_{45} for fourth instar fall armyworm of 2.66×10^8 polyhedral inclusion bodies. These values are much higher than the LD_{50} values reported for fourth instar cabbage loopers treated in the same manner with cabbage looper nuclear polyhedrosis virus.

2. Cabbage Looper. At Riverside, Calif., a cytoplasmic polyhedrosis virus was found infecting cabbage looper larvae. Polyhedra were isolated and purified. The LD_{50} for first instar larvae was approximately 1.5 polyhedra per mm^2 of diet surface area. Fourth instar larvae were less susceptible. Developmental rate of treated larvae is markedly decreased. Cytoplasmic polyhedrosis virus infection also appear to affect pupal and adult stages. Many pupae from larvae-fed polyhedra weighed less than half that of the control groups and increased numbers of deformed moths occurred. Pupal weight was correlated to the number of white or yellow fecal pellets excreted by the treated larvae prior to pupation. Frequently, the white fecal pellets contained large numbers of polyhedra. Cytoplasmic polyhedra in alkaline solutions of 0.1 and 0.01 M Na_2CO_3 + 0.05 M NaCl lost infectivity potential within 10 minutes of exposure. However, .001 M Na_2CO_3 had no effect on the infectivity of the polyhedra after 2 hours of exposure.

Commercial nuclear polyhedra preparations at the rate of 600×10^9 nuclear polyhedra/acre of cabbages gave 61% mortality of cabbage looper larvae. Dibrom at 2 lb/acre gave better control than polyhedra sprays.

Laboratory studies on the virus-host relationship in cabbage looper pupal and adult stages at Riverside, Calif., indicated little or no effect on mating or longevity when moths were injected with 5,000-15,000 times the concentration of virus required to kill fourth instar larvae. However, treated moths were slightly infected as determined by histological examination.

Very high virus concentrations were required to prevent moth emergence by injecting polyhedra into pupae 96-120 hours old. Moths from injected pupae were often severely deformed. After injection of pupae 24-120 hours old with polyhedra virus, infected cells were found in the developing wings, compound eyes, optic lobes of the nervous system, hypodermis, trachea, fat body and developing muscle, and in the ovaries of female pupae.

An apparatus and method for comparatively rapid injection of cabbage looper larvae were designed at Riverside, Calif. A 12- to 18-in. length of polyethylene tubing was sleeved over the needle of a Hamilton Syringe. The opposite end of the tubing was then flared to accept the blunt end of a drawn-glass needle. The assembly was then placed in a microapplicator device. The polyethylene tubing allows the needle to be moved to the larvae for injection and negates individual handling of larvae. Immobilizing 10 to 20 larvae in a bead of honey on the border of a petri dish lid has also added to the speed of injection. After injection larvae are washed out of the honey with distilled water and placed in rearing containers.

Cabbage looper nuclear polyhedrosis virus free of the inclusion bodies was obtained in several ways. Polyhedra were dissolved with alkaline solutions (0.03 M Na_2CO_3 + 0.05 NaCl) or virus was obtained from supernatants of diseased larvae homogenates. Assays against fourth instar larvae of four different preparations of virus liberated from polyhedra indicated that the material was infective. Virus from diseased larvae was much more infectious per unit volume and assays of two different preparations showed no statistical differences in LD_{50} values.

At Mesa, Ariz., cabbage looper field collections throughout the year from various crops and some weed hosts have shown Voria ruralis to be the most prevalent parasite of this insect. Approximately 10-15% of the looper larvae collected during the winter months and 25% from April to June were Voria parasitized. In July and August Voria parasitism reached a low level and from October to December 50% or more of the loopers gathered from the field were found to be parasitized.

Exposure of 300 looper larvae in large field cages with 100 or 200 pairs of Voria flies resulted in 50 and 80% parasitism and recovery of 145 and 484 parasite puparia, respectively.

At Charleston, S.C., field collections of cabbage looper cadavers from cabbage during the 1966 fall season disclosed 2 distinct classes of fungi occurring on several occasions, a Phycomycete, Entomophthora sphaerosperma Fresenius, and a Fungus Imperfecti, Spicaria rileyi Farlow. Immersion of cabbage plants in Bacillus thuringiensis suspensions reduced oviposition of cabbage looper adults to a greater extent than did spraying. Laboratory experiments with 10 different preparations of B. thuringiensis indicated that all 5 instars of the cabbage looper were as vulnerable to the pathogen as those of the imported cabbageworm.

At Charleston, 7 weekly applications of 2 commercial aqueous suspensions of B. thuringiensis, applied alone and in combination with an unpurified local strain of a cabbage looper nuclear polyhedrosis virus, proved inferior to a currently recommended parathion-endosulfan mixture and did not give adequate control of cabbage looper in field plots of 1966 fall cabbage. Parathion-endosulfan gave near-adequate protection against a caterpillar infestation that caused 61% of untreated plants to be considered ineligible to U.S. Grade 1. Bacillus-virus combinations were more effective than either pathogen alone and the local unpurified virus as effective as a commercial purified product. Six weekly applications of a Bacillus-virus combination on 1967 spring cabbage gave near-adequate control of a cabbage looper and was as effective as a parathion-endosulfan mixture. A commercial virus product used alone was about as effective as the 2 mixtures just mentioned. One commercial dust formulation of B. thuringiensis gave excellent control of the looper, another did not. Aqueous and wettable powder sprays of B. thuringiensis were less effective against the looper than the dust formulation. All Bacillus formulations gave good control of imported cabbageworm and diamondback moth.

3. Southern Potato Wireworm. Of 100 dying or dead field-collected southern potato wireworm larvae, 35 had protozoan infection, 13 protozoan and Metarrhizium infections, and 11 were infected by the fungus alone.

4. Green Peach Aphid. At Yakima, Wash., Anthocoris melanocerus was particularly effective in the control of the green peach aphid on broccoli and sugarbeets. The predators deposited 3 eggs per day for 50 or more days and multiplied approximately 48 times in a single generation.

In Walla Walla, Wash., studies under cooperative agreement have shown that parasitic wasps, Aphidius pulcher or A. smithii, were attracted to honeydew produced by pea aphids and to honey.

Growth chamber studies were conducted with A. pulcher parasitizing pea aphids on alfalfa. Mortality was very heavy at 32° C. Levels of parasitization were higher at 21° C and about 80% relative humidity than at 65% and 47% relative humidity or at 10° C. Field surveys related to mass releases of aphid parasites in alfalfa and pea growing areas showed 27% hyper-parasites on Aphidius spp. and 45% on P. pequedorum in October 1966.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Leaf Miner. At Beltsville, Md., aluminum foil, grey aluminum paint on masonite, or clear polyethylene film soil mulches failed to prevent vegetable leaf miner adults from ovipositing in snap bean plots in comparison to unmulched plots. Larvae per leaf averaged 8.1, 8.5, and 6.7, respectively, in the mulched plots and 5.0 in check plots.

2. Aphids. At Farmingdale, N.Y., aluminum foil, aluminum paint on black polyethylene film and aluminum paint on asphalt soil mulches resulted in 98% reduction of trapped aphids, whereas titanium oxide paint reduced yellow trap

collections 80%. Aluminum strips across the ends of the rows were necessary to prevent aphids from moving between strips of aluminum into the plots. Fewer plants with virus symptoms occurred in squash, cucumber, and bean plots with aluminum surface mulches than the plots with white surface mulches. Infections in check plots were significantly higher than in the white mulch. Snap bean, summer squash, and cucumber yields were higher in mulched plots than check plots.

3. Drosophila. At Beltsville, Md., (in cooperation with the Campbell Soup Company, Rancocas, N.J.) 1% apholate, 20% granulated sugar, 6% active dry yeast, and water failed to give satisfactory control of Drosophila melanogaster in 1/2-acre tomato field plots. However, a high percentage of female flies collected from the check plots were sterile and oviposition records from ripe slit tomatoes showed that the Drosophila population was lower in the experimental plots than in untreated tomatoes growing several hundred feet away.

In 24- X 24- X 6-ft plastic screen cages containing tomatoes, baits of 1% apholate (broadcast and in cartons), 0.5% ENT 51146, 2% ENT 50905, 1% apholate (cartons) plus 1 lb diazinon/acre application, or 1 lb diazinon alone reduced Drosophila populations 85% or more. Females sampled from the populations were more than 85% sterile from treatments of 1% apholate (cartons), 0.5 and 2% ENT 50905, and 0.5% ENT 51146. Sterility was less in flies from cages treated with 1% apholate (broadcast), 2% apholate, 2% ENT 51146, and 0.5% ENT 51146 plus 0.5% ENT 50882. No flies were isolated from cages treated with diazinon and diazinon plus apholate due to the low number of flies.

4. Cabbage Looper. At Mesa, Ariz., 413 traps, each with two 15-watt blacklight fluorescent lamps were placed in operation on March 6, 1967, on a 2,500-acre partially isolated ranch near Red Rock, Ariz. The traps will be operated continuously throughout the year to determine the possibility of preventing population increases and consequent injury from several species of lepidopterous insects affecting lettuce, particularly the cabbage looper. All traps are baited with a synthetic female cabbage looper sex attractant. A check area without intensive light trapping is maintained approximately 10 miles away from the Red Rock area. This is a cooperative project with the Agricultural Engineering Research Division.

A maze type mechanical trap baited with the female cabbage looper sex attractant caught more male cabbage looper moths than a pheromone baited 15-watt blacklight trap. In addition, large numbers of male granulate cutworm moths were caught.

A new type of dispenser for cabbage looper female sex attractant has been developed at Mesa and consists of a cotton thread wick in an 8 mm glass tube. The pheromone is placed undiluted in the tube and one filling should last the entire season.

At Riverside, Calif., synthetic cabbage looper sex pheromone on sand in 50 ml beakers in combination with blacklight traps, caught 13 times more cabbage

looper males than light traps alone and 2 times more males than traps baited with 100 live females. The pheromone on sand remained attractive for more than 48 days.

Sex pheromone baited electrocutor grid traps mounted above tub canisters containing emulsified water were found more effective for trapping cabbage looper males than pheromone-baited survey light traps. When the former was supplemented with blacklight, 13 times more male moths were trapped per night. Pheromone-baited electrocutor grid traps without blacklight were quite specific for the cabbage looper males and less than 10% of the total catch were of other species. A canister to trap stunned moths was found essential as 81 to 83% of the trapped moths were found in the canister.

Cabbage looper moth catches from barrel and survey type blacklight traps baited with 100,000 µg of pheromone-treated sand placed at the bottom of the light fixtures caught 1.6 times more male moths in an 8-day period than similar traps baited with pheromone on top of the lamp housing and 2 or 3 times more than survey light traps baited with pheromone at base of the lamp housing.

At Riverside, Calif., a Y-tube apparatus was designed and used to bioassay commercial preparations of the synthetic cabbage looper sex pheromone. The AC_{50} (attractive concentration--50% response) of the pheromone in ether solution and applied on filter paper was found to be 1.08 µg and 95% confidence interval of 0.89 to 1.31 µg. By determining the dissipation rate of 5 µg on filter paper, the actual amount of pheromone to which 50% of the moths responded to was calculated to be about 91 ng/m^3 of air.

To date, 20 analogs and homologs of the sex attractant supplied by the Pesticide Chemicals Research Branch have been bioassayed and all found at least 500 times less active than the pheromone

At a constant dosage of the cis isomer (1 µg) and varying dosages of the trans isomer (0 to 500 µg) of the cabbage looper sex pheromone, male response was reduced at 10 µg or more of the trans isomer. This effect was produced, but to a lesser extent, by 7-dodecyn-1-ol acetate and dodecen-1-ol acetate.

5. Cucumber Beetles. At Charleston, S.C., in cooperation with chemists at Beltsville, Md., approximately 134 chemical fractions of the natural female lure were bioassayed as male attractants. Six of the fractions have been attractive to male beetles.

6. Corn Insects. A laboratory procedure has been worked out at Tifton, Ga., for the collection and isolation of sex pheromone of corn earworm. This pheromone caused a marked response in copulatory activity of corn earworm males when a small amount of the material was aspirated into cages, but no increase was noted in the frequency of mating or the number of spermatophores passed.

Studies with the light trap-chemosterilant feeder were conducted with the corn earworm in Georgia and the effects of 0.15, 0.3 and 0.6% tepa solutions

on field-collected earworm moths were recorded. The 0.15% solution reduced but did not eliminate egg hatch in all instances when the material was held for as long as 7 days in the field and bioassayed after each 24-hour period. The 0.3 and 0.6% concentrations reduced egg hatch and oviposition. Some increases were noted in mortality for each of the treatments indicating that the material is toxic to corn earworm moths in higher concentrations.

In cooperation with agricultural engineers at Tifton, ultrasonics was evaluated for its effectiveness as a repellent to the corn earworm moths. The sound was beamed over the field with a 2-in diameter LTV transducer which emitted sound waves at a frequency of 21 kcs up to a sound intensity of 84.5 decibels, as measured on a B&K sound meter on the B scale. The transducer was revolved at 324 rpm from 6 pm until 6 am during the tests. Effectiveness of the sound was determined by counting corn earworm eggs on plants and collecting moths near the transducer in light traps. There were no significant differences between the number of adults or number of eggs near the transducer and in the check area.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Earworm. In cooperation with agricultural engineers at Tifton, a Dynafog aerosol generator was tested for control of the earworm. DDT was fogged directly onto the corn each day during the silking period. When the corn ears reached optimum roasting ear stage, they were evaluated for insect damage. About 90% of the ears treated were marketable, which was about equal to DDT applied by conventional spray equipment.

2. Southern Potato Wireworm. At Charleston, S.C., 4 blacklight traps with one 15-watt lamp each caught from 3,257 to 5,323 adults of C. falli, with an average of 4,357, between mid-August and late October in sorghum fields. Soil samples indicated that the traps did not significantly reduce the overwintering larval population of the insect 10, 50, and 100 feet from the traps. No differences were found between numbers of wireworm larvae in the soil at the various distances from the traps. Traps located 200 feet inside cultivated fields did not catch significantly higher numbers of adults than did traps placed in narrow uncultivated areas between these fields and wooded areas. Limited observations indicated that the adults do not disperse rapidly through woodlands to nearby uninfested recently-cleared areas. Of 1,779 marked adults released in a well-isolated field, 5.1% were recovered by the end of a week. Fifty-one percent of those recovered were found in areas 10 feet from the release point. Nine marked beetles were recovered 900 feet from point of release; none were found at a 1,160-foot distance.

3. Cabbage Looper. At Forest Grove, Oreg., in cooperation with the Birdseye Division of General Foods, applications of DDT-parathion, mevinphos, or parathion at recommended rates applied to broccoli by helicopter in 15 or 20 gallons of water per acre at approximate 10-day intervals from August 12 to October 7, 1966, kept looper populations at low levels throughout the season.

4. Black Bean Aphid. At Forest Grove, Oreg., 1.75 lb/acre of malathion was applied to pole beans by helicopter at 60 mph parallel to the rows and 8- to 10-ft above the foliage or by airplane at 90 mph across the rows at the same height. Six days after application, from 3 aphid colonies in each field, there were 4 adults and 16 nymphs found remaining on one vine from the helicopter application, while 7 living aphids were found in airplane application plots.

5. Spray vs. Dust Parathion Residue Applications. At Forest Grove, Oreg., parathion, 0.5 lb actual per acre, was applied as 25 lb of 2% dust or as a spray in 40 gallons of water per acre of broccoli in each case. The dust was applied from overhead nozzles, both with and without a static electrical charge, while the spray was applied from the conventional trailing boom position. More than 2 times as much parathion was recovered by chemical analysis from the tops and bottoms of the dust-treated foliage, as compared to the spray-treated foliage.

6. Aircraft Applied Ultra Low Volume Malathion Spray for Lygus. At Forest Grove, Oreg., technical malathion applied August 15, 1966, at 8 oz per acre by fixed-wing aircraft to lima beans gave excellent commercial control of lygus bug adults and nymphs within 18 hours after treatment and more complete reduction in lygus populations 9 days after application.

7. Bals-Turbair Spinning Nozzle Mounted on a Bell Helicopter. A single Bals-Turbair electric spinning nozzle mounted on the aft spray boom mounting of the helicopter, facing back, angled down at 45°, has consistently produced an overall swath width exceeding 100 feet and is well adapted for ULV applications.

G. Varietal Evaluation for Insect Control

1. Leaf Miner. At Beltsville, Md., larval mortality of the vegetable leaf miner in 16 tomato varieties averaged 16% in 25-day-old plants, 37% in 50-day-old plants, and 43.7% in 90-day-old plants. Varieties also differed in levels of resistance to this pest.

Larval mortality of the vegetable leaf miner was also found to increase in 17 tomato varieties and 19 chrysanthemum cultivars with decreased temperatures. In tomato, larval mortality for 17 varieties averaged 6% at 78.8° F, 8% at 74.5° F, and 15% at 70.0° F. In chrysanthemum, larval mortality in 19 varieties at the same three temperatures averaged 42%, 51.4%, and 65%, respectively. Leaf miner larval mortality in lima beans did not appear affected by temperatures from 59.5 to 95.8° F.

In cooperation with the Crops Research Division, all lines of Lycopersicon hirsutum tested were highly resistant to vegetable leaf miner oviposition, indicating resistance for leaf miners for this entire plant species. All lines of L. peruvianum and esculentum tested proved susceptible.

2. Two-Spotted Spider Mites. Resistance to two-spotted spider mites in 7 accessions of Lycopersicon hirsutum and L. hirsutum glabratum under greenhouse conditions was observed at Beltsville, Md. Adult and nymphal mortality was higher on the more resistant accessions.

3. Greenhouse Whiteflies. At Beltsville, Md., whitefly egg and first nymph counts on most Lycopersicon hirsutum (tomato) lines tested have been generally as high as on L. esculentum but higher nymphal mortality and delayed nymphal development have been observed on some lines of the former species. Within two accessions of L. hirsutum, plants are virtually free of nymphs. Adult whiteflies confined to the leaves of the plants died within five to fifteen minutes. Contact with the leaves also proved fatal to mealworm adults.

4. Potato Aphid. At Beltsville, Md., all tomato seedlings with L. esculentum parentage and those of the available accessions of L. pimpinellifolium, hirsutum, and hirsutum glabratum were heavily colonized and mostly killed by potato aphids. Six accessions of L. peruvianum showed a high level of resistance. Attempts to artificially infest resistant peruvianum plants from seedling stage to the seventh true leaf stage were unsuccessful due to high aphid mortality. The few adult females which settled on the resistant plants failed to produce nymphs. Segregation for resistance was observed in all resistant lines and this is to be ascribed to the characteristic self-infertility of individual L. peruvianum plants.

5. Tobacco Flea Beetle. At Beltsville, several accessions of L. hirsutum and L. hirsutum glabratum showed a high level of resistance to adult tobacco flea beetles under field and greenhouse conditions. When given a choice of Lycopersicon species seedlings under caged and natural field conditions, beetles did not feed upon the hirsutum accessions but severely damaged the accessions of L. peruvianum, L. pimpinellifolium and L. esculentum.

When confined upon each tomato line separately, beetles fed only sparingly on senescent yellow leaves of hirsutum accessions and extensively and indiscriminately on leaves of all other Lycopersicon species.

6. Lygus. At Riverside, Calif., 35 lima bean entries in the seedling stage were screened in preference tests for resistance to lygus. Two breeders' lines were least preferred as 76% less lygus bug nymphs were found on them as compared to concentrated Fordhook. In contrast, on two other lines 88 to 94% higher infestation occurred.

7. Sweetpotato Insects. At Charleston, S.C., resistance factors involved in sweetpotato resistance to insects have been shown to be a thick cortex imparting a degree of tolerance, the periderm of most but not all varieties provides protection against insect damage and the flesh of a few varieties is non-preferred by some insect species either because it lacks a feeding stimulant or contains a feeding deterrent.

8. Turnip Insects. At Charleston, S.C., aphids reproduced 3 times as fast on a susceptible turnip variety (Pomeranian) as on a resistant variety (Shogoin). Shogoin also appeared resistant to green peach aphids.

9. Banded Cucumber Beetle. At Charleston, S.C., 430 watermelon, 1,371 cantaloup, and 688 cucurbit varieties and plant introductions were screened for seedling resistance to banded cucumber beetles. One resistant watermelon variety (Sugar Loaf) was found. Approximately 1.5% of the cantaloup introductions and 22% of the varieties were classed as resistant. The cucurbits were relatively tolerant to banded cucumber beetle, Diabrotica balteata LeConte, feeding and approximately half of the varieties and 1.8% of the introductions were classed resistant. In tests with selected susceptible and resistant lines, the spotted cucumber beetle, Diabrotica undecimpunctata howardi Barber, showed an almost identical preference as the banded cucumber beetle. The only factor identified was the absence of cucurbitacin, a group of bitter substances that have been demonstrated to be Diabrotica feeding stimulants. These substances are believed to be the major factor responsible for susceptibility in cantaloups and watermelons. In summer squash there is some evidence that a repellent or feeding deterrent may be involved.

10. Leafhoppers. In India (A7-ENT-44) techniques have been developed for evaluation of resistance to host food by measuring feeding on excised leaf tissues. Differences in leafhopper growth and ovarian development were observed.

11. Corn Earworm. At Tifton, Ga., corn inbreds 81-1 and 471-U6 make up the desirable and earworm resistant sweet corn "Walter's White" and are difficult to maintain and use in a crossing program. Several hybrids made from inbreds produced in a backcrossing program with 81-1 and 471-U6 have shown considerable promise in retaining quality and earworm resistance. Improvement has been made in vigor and shortening the silking date of the 81-1 backcrosses, at least as inbreds. Improvements have also been made in 471-U6 backcrosses as to ease of handling in a hand-pollination program.

A study of the relationship of corn earworm damage with ear husk tightness and larval development indicated highly significant differences among corn lines for husk tightness, depth of larval penetration, and larval weights (7 days after infesting). A highly significant negative correlation coefficient ($r = -.513^{**}$) indicated a relationship between husk tightness and depth of larval penetration. Husk tightness and larval weights from field ears had a highly significant negative correlation ($r = -.582$). Depth of larval penetration in field ears at 7 days and larval weights from these ears showed a highly significant correlation ($r = -.541^{**}$).

At State College, Miss., corn lines selected for varying chemical content were evaluated for corn earworm and fall armyworm resistance. In a field test, corn kernels with low amylose content seemed to have more earworm damage than kernels with high amylose content. In addition, kernels with high lipid or high carotene content had more damage than kernels with low lipid or low carotene. In general, these results are in agreement with a similar test

conducted in 1965. A second part of this test involved a fat analysis of larvae reared on these same corn lines. Indications are that larvae reared on the low amylose corn lines contain the least fat, while larvae reared on the high protein lines contain the most fat. Larvae from the high lipid line contained more fat than larvae from the low lipid line. The opposite was true for the high and low carotene lines.

12. Cabbage Maggot. At Yakima, Wash., some varieties of red radishes were found significantly more resistant than some white radishes to attack by the cabbage maggot.

Also, a moderately early greens type turnip was found more resistant than 38 other varieties to attack by the cabbage maggot. However, this turnip was very susceptible to both the green peach aphid and the cabbage aphid.

H. Insect Vectors of Diseases

1. At Beltsville, Md., the green peach aphid transmitted the virus associated with russet crack of sweetpotato to indicator plants Ipomea var. Scarlet O'Hara and I. setosa and reinfected sweetpotatoes.

The virus appears to be picked up by 10-minute feeding on source plant and transmitted in the non-persistent manner.

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AREA NO. 2. POTATO INSECTS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Concern over problems associated with insecticides which may also include residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, requires that an increasingly strong research effort be concerned with development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

USDA AND COOPERATIVE PROGRAMS

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono and Presque Isle, Maine, Beltsville, Md., and Charleston, S.C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry. Studies on plant resistance are conducted under grants at Pennsylvania State University and, in cooperation with the Crops Research Division, at the Iowa State University of Science and Technology. (Biological control studies at the University of Maine conducted under a cooperative agreement have been completed.)

The Federal scientific effort devoted to research in this area totals 3.6 professional man-years. Of this number 0.1 is devoted to basic biology; 1.1 to insecticidal and cultural control; 0.4 to insecticide residue determination; 1.1 to biological control; 0.1 to insect sterility and attractants; 0.1 to evaluation of equipment for control and detection; 0.1 to to varietal resistance; 0.3 to insects that spread potato diseases; and 0.3 to program leadership.

In addition Federal support of research in this area under grants and cooperative agreements totals 0.8 man-years devoted to plant resistance to insects.

Research under the PL 480 grant program is being supported in India and Poland. Projects in India include research on hereditary variation in the ability of Myzus persicae to transmit potato leaf roll and virus Y (A7-ENT-33) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (A7-ENT-44). In Poland research is underway on the influence of fatty acids and alpha-tocopherol on the lipid metabolism and physiology of the Colorado potato beetle and on vitamin activity in coming generations (E21-ENT-18).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 4.6 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Pacific Coast Wireworm. The presence of a sex pheromone in adult Pacific Coast wireworm females that is highly attractive to male wireworms was demonstrated at Yakima, Wash.

2. Aphids. In Maine, peak aphid populations on untreated potatoes were only about 1/4 as high in 1966 as aphid populations at a comparable time in 1965 and below the threshold numbers where feeding damage reduces potato tuber yield. Entomogenous fungi-infested potato aphids were found on potatoes July 18. The resulting epizootic was virtually complete August 25 and a second epizootic during the last half of August reduced green peach aphid populations. The most common and effective species of fungi were Entomophthora thaxteriana and E. aphidis. A third, less common species was E. planchoniana. Parasite populations were below average as were number of eggs of certain predaceous insects; however, predaceous larvae and adults generally were more abundant in 1966 than in 1965.

In northeastern Maine high buckthorn aphid populations in 1967 were much earlier and larger than during the preceding 4 years on buckthorn, the primary host and potatoes. Entomogenous fungi and parasites were less effective against the buckthorn aphid during late summer and fall 1966 than during any comparable period since 1962. Late spring Canada plum surveys indicated that green peach aphid early summer populations on potatoes in northeastern Maine would be low.

B. Insecticidal and Cultural Control

1. Aphids. Good to excellent potato aphid control was obtained on field grown Katahdin potato plants from single spray applications of Union Carbide UC-20047A (0.75 lb. or 0.38 lb./acre), duPont 1179 (9.50 lb. or 0.13 lb./acre), or Chipman RP-11974 (9.24 lb./acre) in studies in Maine. None of these treatments was superior to parathion (0.1 lb./acre), which controlled potato and green peach aphids. UC-20047 and duPont 1179 (0.5 lb./acre) also controlled green peach aphids.

Ground equipment sprays containing NIA-10242 and Azodrin were about as effective as endosulfan for green peach aphid control on potatoes in Washington.

At Yakima, Wash., emulsifiable concentrates (EC) and ultra low volume (ULV) formulations of malathion applied at 1 lb./acre with an experimental ground sprayer were not effective against the green peach aphid. Low volume applications of endosulfan EC or oxydemetonmethyl EC were more effective than an experimental ULV-endosulfan formulation. The addition of Triton-X to some of the ULV sprays did not improve aphid control.

2. Wireworms. At Yakima, Wash., broadcast applications of diazinon, parathion, and Stauffer N-2790 gave best wireworm control.

Soil applications of a mixture of EPN and parathion (1/2 each) were superior to the same total amount of toxicant applied as EPN or parathion alone for Pacific Coast wireworm control. Also promising was a grits formulation of Stauffer N-2790.

3. Two-Spotted Spider Mite. Azodrin gave outstanding control of the two-spotted spider mites on potatoes in Washington.

C. Insecticide Residue Determinations

1. Wireworms. At Yakima, Wash., a single DDT spray (10 lb) in August prevented wireworm damage to potatoes and harvested tubers contained less than 0.01 ppm DDT.

2. Aphids. In Maine, greenhouse bioassays starting March 25, 1967, showed no residues lethal to green peach or foxglove aphids feeding on caged Katahdin potato foliage of plants from tubers harvested the preceding fall from plants side dressed July 18, 1966, with 1 lb/acre of Union Carbide UC-21149, disulfoton, or Niagara NIA-10242-10 granules.

A ground spraying apparatus was developed by the Agricultural Engineering Research Division in Washington for the application of ultra low volume sprays. Application of malathion with the apparatus showed that distribution was satisfactory, but of the theoretical 1.46 kg/hectare applied only 0.24 kg/hectare was deposited on the filter paper samples placed on the ground. The amount of insecticide which reached the ground did not compare favorably with that deposited by aircraft.

At Yakima, Wash., 10% disulfoton granules were applied as follows: (1) in band treatments at 2.24, 3.36, and 4.48 kg actual per hectare; (2) as side dressings at various periods after planting with 3.36 kg per hectare; and (3) as a combination of the 3.36-kg banding with the 3.36 kg side dressing. Harvested potatoes contained from less than 0.05 to 0.29 ppm for all three treatments.

Also in Washington, endosulfan, malathion, and oxydemetonmethyl were applied to potato leaves as emulsifiable concentrates with conventional ground spraying equipment and as ultra low volume (ULV) sprays with an experimental ground spraying apparatus developed by the Agricultural Engineering Research Division. The insecticide, type of treatment, application rate in kilograms per hectare, and the average residue in ppm immediately after application and 14 or 15 days later were as follows: endosulfan, ULV, 0.9, 23.0, 12.; endosulfan, EC, 1.1, 89.9, 3.9; malathion, ULV, 1.7, 8.5, 0.04; malathion, EC, 1.1, 39.8, 0.01; oxydemetonmethyl, ULV, 0.6, 18.8, 0.1; oxydemetonmethyl, EC, 1.1, 214.6, 2.1.

D. Biological Control

1. Seven-Spotted Ladybird Beetle. In Maine, the introduced 7-spotted ladybird beetle was found to apply an adhesive substance anteriorally on each egg at oviposition. Studies at Rutgers University suggested that egg masses might be successfully broken up by placing a water soluble substance between the adhesive and the oviposition substrate. A coating of 15-33% gelatin proved suitable for this purpose. A satisfactory device for obtaining eggs of this predator was developed. One worker can now obtain eggs from approximately 800 females per day, compared to previous methods when eggs from only 80 females could be obtained.

Seven-spotted ladybird beetle and Chrysopa spp. eggs have been distributed in water or sucrose solution sprays without excessively suppressing hatchability. Chrysopa egg hatch was markedly reduced when applied at a pressure of 30 lb/in^2; C. septempunctata egg hatch was reduced when lower spray pressures were used.

Studies in Maine indicated that diapause can be broken and oviposition maintained by exposing adult C. septempunctata to a nearly continuous source of light from a frosted 100-watt incandescent bulb. Adult diapause appeared to be influenced by food in the larval stage. Surplus food in the adult stage is necessary for initiation and/or maintainance of oviposition. For adult pairs this is in excess of approximately 200 green peach aphids per day. At lesser numbers of aphids, oviposition could be increased by supplying a liquid food supplement every other day.

Factors affecting oviposition of the predator, Coccinella septempunctata, were found to be crowding in the oviposition cage and the chemical nature of materials covering the cage or used to band-treat cage walls. Crowding was successfully overcome by providing extra resting space through introduced excelsior. A narrow band of "Teflon" on the cage walls, or a cage covering of Saran wrap caused the females to become very active and deposit many small clusters of eggs.

E. Insect Sterility, Attractants, and Other New Approaches to Control

Tests were initiated in Maine to determine the possibility of eliminating the green peach aphid in a semi-isolated 100-square-mile area by removing its

overwintering host plant, Canada plum. In 1967 surveys indicated that 70% of the thickets were located in 1966 and the remainder were removed in 1967.

In 1967 a second experiment was initiated to remove Canada plum in a non-isolated 315-square-mile area in central Aroostook County. Approximately 450 Canadian plum thickets were found. These are being removed.

F. Varietal Evaluation for Insect Control

1. Aphids. Under competitive conditions in Maine larger populations of potato and green peach aphids developed on Katahdin than on Kennebec potato varieties, but the latter variety had more buckthorn aphids. In one location Kennebec potatoes had more leaf-roll infection than Katahdins but in three locations the reverse was true.

2. Two-Spotted Spider Mite. At Pennsylvania State University investigations have been initiated to study population increases of two-spotted spider mites and factors involved in spider mite host association under a grant.

3. Potato Leafhopper. Histochemical studies in Iowa indicate positive mucopolysaccharide reactions of fluids discharged into plant tissues along with potato leafhopper eggs. Salivary secretions of the leafhoppers are being tested for suspected hydrolytic enzymes. Studies of postembryonic development show discharge of yolk laden primary oocytes from the ovarioles on the fourth day of the adult stadium and presence of spermatozoa in seminal vesicles on the first day. Apparently feeding must immediately preceed oviposition; refusal to feed prevents oviposition.

G. Insect Vectors of Disease

1. Aphids. Leaf-roll spread in susceptible Chippewa variety potatoes ranged from 0.3 to 1.3% in Maine where insecticides were applied. In untreated, less susceptible Katahdins leaf-roll spread averaged over 6%. There was no differences in leaf-roll spread between plots treated with several effective systemic aphicides applied in the planting furrow, or of two foliar spray applications of a mixture of methyl parathion and endrin.

In Maine 3 or 6 weekly applications of a special mineral oil emulsion in water provided a highly significant degree of protection (about 60%) to Green Mountain potatoes from potato virus-Y infection spread by green peach aphids. Six applications gave better protection than three. There were no differences in sizes or trends of aphid populations on Chippewa potatoes sprayed 4 times at weekly intervals and 2 times at biweekly intervals with 2 1/4 lb per acre of chlorocholine or with water alone.

The unusually mild winter of 1966-67 in Washington was extremely favorable for the survival of green peach aphid summer forms on winter hardy weeds.

In eastern Washington green peach aphid overwintering eggs are most commonly laid on peach but occasionally on apricot. Observations in the spring of

1966 indicated that small numbers of the green peach aphid are deposited on Solanum dulcamara, a woody, solanaceous plant. Apterous forms were found on this shrub May 23, 1966, at Walla Walla and May 21, 1967, at Caldwell, Idaho.

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AREA NO. 3. DECIDUOUS FRUIT, TREE NUT, GRAPE, AND BERRY INSECTS

Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes, and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural, and other nonchemical methods of control are available for comparatively few insect pests. Much dependence is placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish, and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical, and safer insecticides; and for intensified research on alternate types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and materials that affect insect growth and reproduction, including chemosterilants. More research is needed on integrated chemical-biological control programs with less intensive insecticide usage, so that the maximum benefits from parasites, predators, and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, and to determine host preferences, distribution, and habits of the insect vectors, and method of population suppression. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry, and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md., and Riverside, Calif. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division. Work is also being conducted

under grants at the Washington, North Carolina, California, Oregon, Kentucky, Pennsylvania, Maine, Texas, New York, Ohio, and Colorado Agricultural Experiment Stations, and at Brigham Young University in Utah.

The Federal scientific effort devoted to research in this area totals 20.0 scientific man-years. Of this number 3.9 is devoted to basic biology and nutrition; 5.1 to insecticidal control; 1.1 to insecticide residue determinations; 2.9 to biological control; 4.8 to insect sterility, attractants, and other new approaches to control; 0.2 to evaluation of equipment for insect detection and control; 0.8 to insect vectors of plant virus diseases; and 1.2 to program leadership.

In addition Federal support under grants provides for a total of 5.4 scientific man-years of research in this area. Of this total 1.8 is devoted to basic biology, physiology, and nutrition, 1.0 to biological control, 2.3 to insect sterility and attractants, and 0.3 to varietal resistance.

Research under PL 480 grants is underway as follows: Israel (A10-ENT-13) on factors influencing variations in insecticide resistance, including resistance of spider mites to insecticides; Poland (E21-ENT-8) on study of mites in orchards with special reference to the relation between phytophagous and predaceous species, and (E21-ENT-16) on populations trends of predaceous arthropods in apple orchards sprayed with pesticides and the influence of the trends on population density of phytophagous mites and other pests; and Yugoslavia (E30-ENT-2) on leaf miners in orchards and (E30-ENT-4) on spider mites in orchards.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 48.5 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. Expansion of facilities at Yakima, Wash., facilitated rearing up to 8,000 moths per day on an artificial medium. Moths reared for 34 consecutive generations on this medium showed no retrogression compared to stock reared on natural foods. Cost per 1,000 adults was reduced from $5.53 (materials only) in 1965 to $1.90 in 1966. Work in progress shows promise of reducing the latter by one-third. Costwise, the artificial medium holds a favorable position over apples but efficient egg utilization and control of fungal contaminants continue to be intermediate problems. Progress was made in developing equipment designed to mechanize the rearing procedure.

Studies at Washington State University under a grant indicate that photoperiod is more significant than low temperature for inducing diapause in the Washington strain of the codling moth. When held on 16-hour photoperiod, significant pupation occurred even at 15° C, a temperature near the developmental threshold. The studies indicated that photoperiodic induction of

diapause was most effective within the first 3 larval stadia. Also photoperiod appeared to be the most significant environmental factor for breaking diapause. Diapause larvae held for three weeks at -9° C did not continue development when placed at 26° C on 12-hour photoperiod, but did pupate at the high temperature when on 16-hour photoperiod.

In studies involving diapause prevention and termination with skeletal photoperiods, discontinuous light supplementation at the proper time significantly reduced diapause normally experienced at short photoperiod, and the nature of supplemental light governed the time for greatest effect. When the last daily light experienced was measured from start of the continuous 10-hour exposure, the following peaks of pupation were obtained: Single flash at 15 hours yielded 90% pupation, 4 flashes at 17 hours yielded 80% pupation, 1 flash at 16 hours yielded 82% pupation. Light supplementation with flashes was not successful in breaking diapause.

2. Peach Tree Borers. The sex ratio of 73,667 adult lesser peach tree borers reared in the Vincennes, Ind., laboratory, and 18,638 additional adults recovered from caged peach wood was determined at 53 males:47 females.

In dissections at Vincennes of 47 living female lesser peach tree borers caged with 240 males, each female contained a single spermatophore, indicating that the females had mated only once.

In temperature-humidity tests with the lesser peach tree borer at Vincennes, egg hatch was nearly 81% at 70° F, while only 54% hatched at 90° F. The incubation period was 9 days at 70° F, compared to 6 days at 90° F. There was a general trend of increased embryo survival as the humidity increased, reaching maximum survival in the 72-78% relative humidity range.

At Fort Valley, Ga., peach tree borer cocoon collections and adult emergence records showed that cocooning was maximum at the end of August and adult emergence was maximum in mid-September. First moth emergence was recorded in mid-June; subsequent emergence was low until late August.

Field-collected peach tree borer cocoons held in environmental chambers at Fort Valley under altered days emerged as adults and the females began calling in synchrony with the altered day. Emergence came about $\frac{1}{2}$ hour after "sunrise" and calling started $3\frac{1}{2}$ hours after female emergence. Males emerged about 8-10 minutes before females. Entrainment was virtually complete, though the period of entrainment was not determined. The emergence and calling rhythms were moved both forward (6:00 AM EST "Sunrise") and back (10:00 AM EST "Sunrise") from the solar day.

At North Carolina State University in research under a grant, peach tree borer larvae were reared on green apples or peach seedlings, transferred to artifical medium or kept on green apples. Mating activity was initiated in laboratory cages soon after lights were turned on. Females usually mated within a few hours after emergence and apparently only mated once. Males were mated daily to virgin females for 6 days without any effect on fertility.

3. Plum Curculio. At Fort Valley, Ga., biological studies on non-diapause plum curculios enabled further improvement in laboratory rearing procedures. Eggs laid per apple was closely related to the size of apple and surface area exposed; the smaller apples were superior. Also more and larger larvae were produced per gram of apple from 12-gram apples than from 20-gram apples. Larvae placed in soil for pupation reached their pupation depth in 3 days and started forming pupation cells on the fourth. Pupae began forming on the ninth day and adults appeared on the 17th or 18th day. Some adults had worked their way to within an inch of the soil surface by the 24th or 25th day. The larvae pupated well below the 1/2 - 2 inch depth usually reported. High soil moisture was very detrimental to pupating larvae. When surface evaporation from pupation trays was restricted, adult emergence fell from 90% to 57%.

Larvae weighing less than 17 mg failed to survive the pupal stage as well as larger larvae. Ten percent fewer small larvae emerged as adults than larvae weighing over 17 mg. Larvae that pupated at 80° F did not survive the pupal stage as well as those that pupated at 75° and 70° F. Ten percent fewer adults emerged from 80° conditions than from the 70° F. chambers. The minimum pupation period was shortened from 35 days at 70° to 27 days at 80° F. The small adults arising from small larvae reared under crowded conditions were as long lived as larger adults. For 8 adult weights ranging from 8.9 to 10.5 mg, there was about 50% mortality after 10 weeks of adulthood.

4. Pecan Insects. In mating studies of the hickory shuckworm at Albany, Ga., emanations from developing pecan foliage, phylloxera galls, and pecan nuts stimulated moths to mate. The stimulation was not a tactile response nor was it induced by emissions from mature pecan foliage or pecan nut extracts made following present procedures. Water, hexane, acetone, and chloroform extracts also failed to elicit a mating response.

A method was developed at Albany for rearing the hickory shuckworm on an artificial diet. The refinement of procedures, surface sterilization of the eggs and the addition of antibiotics to the diet showed promise of reducing contamination and increasing yields.

Other studies on hickory shuckworm at Albany showed that the larvae pass through five distinct stadia and overwinter in the fifth. Storage of fifth-instar larvae in shucks, nuts, or artificial diets followed by rearing of the moths as needed provided the laboratory with more than 28,000 moths; larval mortality during storage was not excessive. The production of large quantities of moths during July and August by this method for sterility or attractant studies appeared feasible. Moths were also stored in polyethylene containers for as long as 15 days at 10° C.

Dissection of 135 female hickory shuckworm moths collected in blacklight traps at Albany yielded an average of 1.56 spermatophores in the bursa copulatrix of each female. Sixty-nine percent had mated once, 17% twice, and the remainder 3-6 times. There appeared to be a correlation between spermatophore size and number; small spermatophores usually were found in larger numbers. Perfectly-formed spermatophores were often found inside the shell of larger

ones. Sometimes a third one was found inside the second. Often, small spermatophores were packed sardine-like in the bursa copulatrix, partially inside each other or in no particular order.

At Albany, two species of spittlebugs that attack pecans oviposited readily in cages containing living pecan leaves. The eggs, which were deposited under the epidermis of new terminal growth and leaf petioles, hatched in about 1 month.

5. Miscellaneous Insects of Deciduous Fruits. The sex ratio for the Vincennes, Ind., laboratory culture of Trichogramma minutum was established at 56 males:44 females. Progeny, living to adulthood, averaged 30.1 per female. Thus, the culture had the reproductive potential for a 17-fold increase per generation with an average of 10 days per generation.

At Vincennes exposure of 2-day-old red-banded leaf roller eggs to 0° F, 57% relative humidity for 2 to 7 hours killed leaf roller embryos but did not materially affect successful parasitization by Trichogramma minutum.

Survival of Trichogramma at Vincennes under cold storage conditions was improved by holding parasitized red-banded leaf roller eggs at 50° F and 88 to 100% relative humidity. However, the parasites tended to emerge prematurely in the cold storage boxes if held at room temperature more than 3 days before placing in storage. There was no emergence in the cooler at the end of 1 month from eggs that had been parasitized 1-3 days before storage. However, there was 15 to 60% emergence in the refrigerator from eggs that had been parasitized 4 to 7 days prior to cooling. The 1- and 3-day-old group had 64 to 78% emergence when returned to room temperature, with no apparent irregularities in sex ratio, behavior, or searching ability.

At Fort Valley, Ga., newly emerged shot-hole borer adults caused serious damage to peach buds in orchards near unburned piles of bulldozed peach trees. Maps made of the injury patterns in orchards surrounding the infestation source showed that migration occurred readily across open fields for at least 0.2 mile but that little migration occurred through woods.

Progress was made at Wooster, Ohio, in developing a rearing method for blueberry maggot; 546 third-generation puparia were obtained in insectary conditions from a culture of 80 overwintering puparia using fresh blueberries as the food media.

Yellow-colored sticky boards caught significantly more adult walnut husk flies at Wooster than green boards similar in color to immature black walnut husks.

Grape berry moth pupae were held at a constant 40° F in the Wooster laboratory for over 18 weeks without significantly decreasing the time required for adult emergence or increasing pupal mortality. This offers an improvement over the previously-used technique of storing pupae overwinter under

outdoor conditions. Virgin female grape berry moths, placed within sticky tubs, attracted male moths of the overwintering generation.

Female apple maggot adults deposited more eggs in paraffin domes in the laboratory at Wooster when a section of fresh apple was placed under the dome.

At the University of Maine in research under a grant, yellow sticky board traps were three times as attractive to apple maggot flies as red or blue sticky boards or liquid bait mason jar traps in luring apple maggots to chemosterilant residues. Apple maggot puparia collected from field infested fruit required a cold period of 90 days at 32° F to break diapause and permit emergence. Many field collected puparia were parasitized by Opius melleus Gahan. Apple maggot laboratory colonies were developed using cull apples for larval food. Adults were held in half-pint cartons, and exposed to apholate, 5 fluoroorotic acid, hemel, and hempa. Hemel was the most promising chemosterilant.

In New York under a grant, a non-diapausing strain of oriental fruit moth was selected for 80° F and 12-hour light. Selections are being made for lower temperatures and for a diapausing strain.

In studies at Brigham Young University under a grant to determine the ecology of mites within pomaceous tree fruit orchards, 60 commercial and 105 abandoned orchards were surveyed to determine the mite fauna. The following phytoseiid mites were identified: Typhlodromus mcgregori, T. occidentalis, T. smithi, T. oregonensis, T. caudiglans, T. cucumeris, T. fallacis, and T. marinus. Also two new species were found and 4 others are likely to be new when positive identifications are made. Tetranychid mites identified were: Bryobia rubriculus-arborea, B. praetiosa, Panonychus ulmi, Eotetranychus willamettei, E. carpini, Tetranychus mcdanieli, T. canadensis, and T. telarius.

Studies at Washington State University, Wenatchee, Wash., under a grant revealed the following characteristics of pear psylla mating behavior: (1) Mating is necessary for the production of fertile eggs. Mating also speeds egg development and increases egg production. Unmated females deposit only a few infertile eggs. Females must mate at least once every 10 days over a period of 60 days for maximum egg production which averaged 664 in these studies. (2) Each male was capable of mating 6 females to full egg capacity under caged conditions. Ratios in excess of 4 males to 1 female reduced egg production, indicating that excess mating interferes with the female's normal activities. (3) Females mated successfully within a few hours after their final molt while males required about 2 days to reach sexual maturity. (4) Males were the aggressors in mating activity; they sought out the females by randomly walking over the foliage. Females remained quiet during the time they were receptive. The duration of copulation varied from less than 1 minute to as long as 3 to 4 hours but usually was less than 20 minutes. (5) Mating of overwintered females in the spring was required before they deposited fertile eggs, even though they copulated readily in the fall. There was no successful storage of sperm by females over the winter.

In Poland (E21-ENT-16) surveys of arthropods in orchards were made and populations of predators, mites, and other pest species determined. Methods for counting mites on field-collected leaves were evaluated. Short term effects of fungicides, ovicides, and insecticides were established against several predaceous and pest species.

In Yugoslavia (E30-ENT-2) the appearance, distribution, and severity of infestation of 5 species of leaf miners was determined. Biological studies of 2 species, Stigmella (Nepticula) malella St., and Lyonetia clerkella L., were undertaken. The effects of 5 insecticides on S. malella and its parasites were determined. Ten species of Eulophidae parasitized this leaf miner.

B. Insecticidal and Cultural Control

1. Codling Moth. At Vincennes, Ind., the effect of normal weathering on Shell SD-8447, Niagara NIA-10242, General Chemical GC-6506, carbaryl, and azinphosmethyl after 3 cover sprays was determined by field-laboratory bioassay. Two-hour-old deposits of all treatments were 100% effective against larvae and adults of both codling moth and red-banded leaf roller. GC-6506 was still effective against larvae of codling moth after 22 days of weathering. SD-8447 and azinphosmethyl were effective against larvae of the red-banded leaf roller after 22 days. Only NIA-10242 was effective against adults of either species after 14 days of weathering.

In field-laboratory bioassays at Yakima, Wash., Shell SD-8447 and Geigy GS-13005 both gave 100% mortality of codling moth adults on twigs and larvae on fruit for five weeks after application. Both materials compared favorably with the standard treatment of azinphosmethyl.

2. Orchard Mites. At Kearneysville, W. Va., further tests with polyflavonoids confirmed earlier findings that these materials may act as mite suppressants. Iron polyflavonoid was the most active of the group tested; however a combination of all of the metallic polyflavonoids (Fe., Mg., Mn., Zn., and Cu.) was more effective than iron polyflavonoid alone. Foliar applications of these materials may fit into an integrated control program if their effect on predatory mites proves minimal.

In laboratory screening tests at Vincennes, Ind., ENT-27,375, ENT-27,552, ENT-27,320, and ENT-27,405 gave 95-100% control of spider mites 7 days after foliar application. ENT-27,405 also gave 100% control when used as a systemic treatment.

In orchard tests on apples at Yakima, Wash., Azodrin, ENT-25,962, and ENT-27,226 gave excellent control of McDaniel and European red mites with two applications during the season. ENT-27,323 and ENT 27,323-X gave good control of mites but were phytotoxic.

At Wooster, Ohio, the following spray materials and spray schedules gave acceptable control of European red mite on Concord grapes: Dicofol combined with the regular grape spray schedule in the prebloom, petal fall and 1st cover sprays; or a dormant spray of 2% Superior-type oil, either 60 or 70 viscosity; or the addition of azinphosmethyl to the regular petal fall, 1st, and 2nd cover grape sprays.

In Israel (A10-ENT-13) strains of the carmine spider mite highly resistant to malathion were found. Preliminary studies suggested that the level of resistance in the mites was positively correlated with nitrogen levels, and negatively correlated with phosphorous levels in the host plants.

3. Pecan Insects. At Albany, Ga., duTer applied at 0.4 and 0.8 active ingredient/100 gallons gave effective control of the spider mite, Eotetranychus hicoriae, but was ineffective against the black pecan aphid.

At Shreveport, La., ULV azinphosmethyl applied by airplane with a micron air system at the rate of 2.6 pounds active/acre gave as good control of the nut casebearer as the same material applied at the rate of 1 pound active in 5.5 gallons of water/acre.

4. Miscellaneous Insect Pests of Deciduous Fruits. At Fort Valley, Ga., only EPN, parathion, and azinphosmethyl, of the currently recommended insecticides, performed well against the plum curculio on peaches. Performance of dieldrin was poor. Carbaryl was effective only when synergized with piperonly butoxide. Mevinphos was more effective than carbaryl at zero day residue. GC-6506, GS-13005, NIA-10242, SD-8447, and Imidan were the most promising new insecticides.

Insecticide and insecticide-oil combinations applied in the fall at Fort Valley for control of encrusted white peach scale were largely ineffective. Only NIA-10242 with 2% superior oil showed any promise.

In Yakima, Wash., tests with UC-21149 granules, for control of pear psylla, 20 or 40 ounces per tree applied to the root area and soaked into the soil gave effective control for the entire season.

Yakima tests with "Superior" type oils of various viscosities; applied at a concentration of 2% during the delayed dormant period gave the following mortalities of San Jose scale: 90 vis., 99.5%; 80 vis., 97.4%; and 68 vis., 98.6%. A count of scale before spraying showed 85% alive.

At Kearneysville, W. Va., NIA-10242 was the most effective of 3 materials tested for control of the lesser peach tree borer.

At Wooster, Ohio, bait sprays to control apple maggot in a backyard orchard for the past 3 years have reduced infestation to a trace; adult flies were caught on sticky board traps in limited numbers.

At Wooster 2 sprays of carbaryl gave effective control of eriophyid mites on butternut leaves; the sprays were applied 8 days apart, when leaves were about half developed. The addition of malathion to the carbaryl gave no advantage.

At Wooster a single application of lindane gave good control of the hickory gall aphid when the spray was applied at the time the hickory buds were swelling.

In studies at Wooster the presence of walnut husk maggots in the husks of black walnuts did not appear to influence the weight, nor the quality, of the nut kernels.

C. Insecticide Residue Determinations

1. At Wooster, Ohio, laboratory studies indicated that Primary Food Color FD 7 C Red #2 (amaranth), used in water alone or in a mixture with insecticides and fungicides, offers a good indicator for comparative studies of spray deposits on glass plates and glass marble rosettes. Amounts of spray deposits were determined by colorimetric methods in studies of various types of experimental sprayers for grapes.

D. Biological Control

1. Codling Moth. At Vincennes, Ind., periodic releases during July and August, 1966, of Trichogramma minutum at the rate of about 100,000 parasites per week into 2 apple trees resulted in a reduced number of second-brood codling moth larvae in the fruit of treated trees, as compared to nearby untreated trees.

Studies at Vincennes indicated that codling moth larvae, infected with granulosis virus when the larvae were 15 days old, produced the highest yield of virus particles at the time of larval death. Age groups of 1, 5, 10, 11, 15, 18, and 20-day-old larvae were tested.

2. Orchard Mites. In observations at Yakima, Wash., in 2 apple orchards receiving little or no seasonal insecticides, McDaniel mites built up to their highest economic levels in July but were practically eliminated by the predaceous mite, Typhlodromus occidentalis, by August. Observations on the distribution within trees of Typhlodromus mites in relation to McDaniel mites showed that the latter tended to concentrate in the center of the trees at the start of the season and migrated to the outer portions of the trees during the second and third generations. Migration of Typhlodromus followed the same pattern but lagged behind, giving the McDaniel mite time to cause some leaf injury before the predator arrived and increased in sufficient numbers to be effective.

Research in Poland (E21-ENT-8) demonstrated the high susceptibility of the predaceous mite, Typhlodromus finlandicus, and related species to about 30 pesticides and the depressing effect on predator populations by several seasonal spray programs.

3. Miscellaneous Insects of Deciduous Fruits. Studies at Vincennes, Ind., revealed a very low rate of parasitism of the lesser peach tree borer by larval and pupal parasites. Of 18,638 adult moths collected from caged peach wood in 1966, there were only 50 recognized parasite adults collected, for a parasitism rate of 0.27 percent. The American plum borer was present in lesser numbers (841 adults), with a higher rate of parasitism (5.5%) by the larval parasite, Idechthis nigricoxalis (Devorgilla sp.). The 20-fold differential in parasitism of these 2 peach-boring insects may account, in part, for the greater pest potential of the lesser peach tree borer.

At Yakima, Wash., parasitism of wolly apple aphid by Aphelinus mali reached a peak of 63% by early October 1966 in a 15-acre experimental apple orchard receiving sterile male releases in lieu of insecticides for control of codling moth. Although this important parasite has declined in recent years with the widespread use of insecticides, these observations demonstrate that it is capable of rapid recovery in the absence of insecticide treatments.

At Fort Valley, Ga., several nematode parasites of the genus Neoaplectana were taken from field-collected peach tree borer cocoons.

In studies at Ohio State University under a grant, overwintering mite eggs on trees receiving a commercial spray schedule numbered 1,174 eggs per foot of twig compared to 20 per foot for trees on an integrated spray program. Several species of mite predators were common on trees in the integrated program. Aphids were also controlled by predators in trees receiving the selective insecticides. However, predators did not provide significant control of codling moth, Carpocapsa pomonella (Linnaeus), apple maggot, Rhagoletis pomonella (Walsh), plum curculio, Conotrachelus nenuphar (Herbst), or green fruitworms.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Codling Moth. Control of codling moth by release of sterile moths continues to show promise. In 1966 sterile male moths were released in a 15-acre block within a 500-acre commercial orchard at Yakima, Wash. Sex attractant traps indicated an average ratio of 270 released male moths to each native male. At harvest, 0.038% of the apples from the release plot were infested with codling moth larvae, compared to 0.077% infestation in nearby blocks treated with conventional insecticides.

In 1967 a mixed-sex release of sterile codling moths was initiated in a 93-acre plot near Yakima. A sterile:native moth ratio of about 40:1 has been maintained. As of July 1, codling moth control in the release orchard was equal to or better than that in orchards treated with pesticides.

The codling moth infestation in apples in a 29-tree semi-isolated orchard near Yakima was reduced from 50% in 1965 to 2% in 1966 through release of mixed sexes of irradiated moths after a single pre-release treatment with parathion to reduce a suspected high population of overwintering moths.

In other Yakima studies, female codling moths treated with 30 and 60 µg of metepa and mated with untreated males laid 0.2% and 0% viable eggs, respectively. Untreated females mated with males treated with 30 or 60 µg of metepa laid no viable eggs. A normal number of matings occurred in each experiment.

Evaluation of the codling moth sex pheromone by Yakima personnel in field cage facilities at Brownsville, Tex., revealed the following: (a) Moth catch per trap (100 1-gallon paper traps/acre) increased as pheromone on blotter paper was increased from 100 to 1,000 to 10,000 female equivalents of extract, (b) trap density (100, 50, 10, 2 traps per acre) of traps baited with 1,000 female equivalents of pheromone did not greatly influence moth catch per acre or number of matings per female, (c) the percentage of mated females increased as the ratio of males:females increased as follows: 1:9, 23%; 1:3, 48%; 1:1, 62%; and 9:1, 81%.

2. Peach Tree Borers. At Vincennes, Ind., sixty 4-vane sticky traps, each containing 6 virgin female lesser peach tree borers, were placed for the second year in the 45-acre Patoka, Ind., peach orchard on April 20. A total of 6,408 virgin females were used during the period, April 20-June 30, 1967, during which time 1,150 native males were captured. At a comparable time in 1966, a total of 3,420 females were placed in traps and 1,514 males were captured.

Marked males were released in the center of the 45-acre peach orchard at Patoka to determine the efficiency of the 360 caged virgin females to attract migrant males. Of 120 marked males released on May 27, 75.0% were caught in the traps; 90.1% of 719 males released on June 12 and 78.6% of 728 males released on June 18 were also caught. In releases made at the four cardinal directions from the orchard, 47% of 602 males released at the 1/4-mile distance, 43.1% of 589 males released at the 1/2-mile distance, and 22.5% of 581 males released at the 3/4-mile distance were recovered from the traps in the orchard.

Studies of virgin female lesser peach tree borers, caged in traps and placed in a peach orchard at Vincennes, demonstrated that 1-day-old females were more attractive to males than older females. A few females remained attractive when 9 days old, but most activity ceased after the fifth day.

Lesser peach tree borer males were caught at Vincennes in traps baited with sex pheromone extracts, prepared by macerating virgin female abdominal tips in either acetone, ethyl alcohol, benzene, hexane, or methylene chloride. These extracts were effective in both cage and open-field tests. Present extracts are not as effective as live virgin females and last only a few hours.

3. Pecan Insects. At Albany, Ga., extracts of whole 1- and 2-day-old virgin female hickory shuckworm moths soaked for 3-3 1/2 hours in methylene chloride elicited strong positive responses from several male moths in the laboratory. When the extract was applied to paper strips and the solvent evaporated, responding males ran wildly over the paper strips while beating their wings.

In studies at Texas A&M University, under a grant, pecan weevil larvae were treated with 1, 5, or 10% apholate or irradiated with 500, 2,500, 12,500, or 62,500 r from a gamma cobalt 60 source. Mortality of larvae irradiated at 62,500 r was 48% in 23 days, and 18% or less for the other treatments.

4. Miscellaneous Insect Pests of Deciduous Fruits. At Fort Valley, Ga., male and female plum curculios were exposed to gamma radiation when 0 to 2, 5 to 7, or 10 to 12 days old and the subsequent effects on feeding and longevity were observed: (a) The 2 sexes and the 3 age groups all responded similarly, (b) longevity and feeding were not greatly affected at 2 and 4 kr, (c) at 8, 16, and 32 kr, LT 50's were slightly over 12 days, (d) at 8, 16, and 32 kr, feeding declined sharply 2 to 4 days before mortality began to rise, (e) at 8, 16, and 32 kr, mortality was not appreciable through 8 days, however, at 10 days following exposure, mortality had started to rise sharply and at 30 days it was nearly complete.

At Riverside, Calif., pear psylla males were sterilized when exposed to pear seedlings dipped in a 3% solution of the chemosterilant tepa. An exposure of 2 hr to the chemosterilant was effective. Virgin females mated with the treated males deposited sterile eggs.

At Wooster, Ohio, corn protein hydrolysate (SIB #7), containing dibasic ammonium phosphate, caught 3.8 times as many apple maggot adults as the bait without the ammonium compound.

In studies at the University of California, Berkeley, under a grant, the radiation dose for inducing optimum dominant lethality in the navel orangeworm was 50 kr for pupae and 60 kr for adults. Pheromone traps were useful in evaluating field populations. A methylene chloride extract of excised female abdominal tips elicited typical mating behavior in males. The pheromone was also highly attractive to the meal moth.

Techniques have been perfected for rearing oriental fruit moths at Grand Junction, Colo., under a grant. An estimated 300,000 moths were produced for research investigations. Cost of labor and expendable supplies for rearing amounted to about $2.66 per thousand moths.

F. Evaluation of Equipment for Insect Detection and Control

1. Codling Moth. At Yakima, Wash., male codling moths responded to the female sex pheromone at temperatures below that at which they responded to blacklight emissions. The two attractants were equally effective at normal summer temperatures. Thus, traps baited with the sex pheromone were more effective than blacklight traps beginning at blossomtime and continuing for approximately a month thereafter. Sex attractant trap catches decline during the second half of the growing season while blacklight trap catches remained the same or increased. During the first half of the growing season, combining live females (sex pheromone) with blacklight doubled the number of moths caught at the trap locations. Indications are that one or perhaps both traps capture only a fraction of the moths actually attracted to them.

2. Pecan Insects. At Albany, Ga., a method was developed for mechanically removing most of the unwanted insects from the small pecan insects collected in blacklight traps. Passing the insect collection through a series of sieves and a blower-separator eliminated most of the larger moths and beetles, reducing the sample size by about 80% by weight.

Hickory shuckworm moths marked with fluorescent pigment were released at Albany on several occasions to test efficiency of blacklight traps. In 10 releases, recovery ranged from 0 to 29.3% and averaged 9.7%. Moths were recaptured up to 5 days after release. Moth age and physical condition at the time of release appeared to important considerations in the success of a recovery. In similar release-recapture studies, moths were released inside a 17 x 17 x21 ft cage covering a tree and 1 light trap near Albany. Recovery ranged from 17 to 60% with an average 29% recovered from 7 releases. Again moths were not recovered after 5 days from time of release.

3. Miscellaneous Insect Pests of Deciduous Fruits. At Wooster, Ohio, minor alterations of an experimental air-blast, concentrate grape sprayer by the Agricultural Engineering Research Division failed to give acceptable visible spray coverage to Concord grapevines trained to the Geneva double-curtain trellis system. However, a "T-shaped" boom, combined with the conventional set-spar boom, gave acceptable visible coverage when used with a hydraulic sprayer at the rate of 200 gal/acre to grapevines trained to the double-curtain system.

The pear psylla, vector of pear decline, showed positive response to blacklight under laboratory conditions at Riverside, Calif. A 15-watt BL lamp was more attractive than a self-filtered BLB lamp. Green, cool-white, gold and red fluorescent lamps were less attractive than blacklight. In the field the 15-watt BL lamps failed to attract psylla, however, 32-watt BL lamps attracted numbers approximately equivalent to those attracted to and captured by the standard yellow sticky-board traps.

G. Varietal Evaulation for Insect Control

1. At Riverside, Calif., two-spotted spider mite populations on 3 of 30 strawberry varieties were considerably lower than populations on all other varieties. Shasta had the highest mite population.

At Lexington, Ky., under a grant cooperative with Crops Research Division, marked differences in severity of spider mite feeding damage occurred on strawberry varieties and seedling crosses in greenhouse tests conducted at normal daylight periods in the winter. Progeny of crosses between two resistant parents were generally more resistant than were progeny of selfed-resistant plants or resistant X susceptible parents. Proteinaceous extracts from resistant and susceptible varieties of strawberries are being studied to identify the amino acids in the two plants and correlate them with the amino acid requirements of spider mites in artificial diets.

I. Insect Vectors of Diseases

In detection work in collaboration with regulatory agencies (PPCD, California Department of Agriculture, and County Departments of Agriculture) the peach mosaic vector mite was found in Madera County, 25 miles farther north than previously recorded in the important northern California peach area, and 160 miles north of any known infections of peach mosaic virus.

The effects of pear decline virus vs. pear psylla toxins in pear trees were compared at Riverside, Calif. Healthy pear trees, in a screen cage experiment, after exposure to viruliferous pear psylla from a pear decline-infected orchard expressed symptoms typical of pear decline disease. Trees similarly exposed to nonviruliferous insects from a decline-free orchard remained normal. Exposure to pear psylla was made in 1964 and the vector was eliminated from the cages at the end of 1964 growing season. Growth measurements and tree vigor recorded to 1967 indicates no permanent adverse effects of toxins injected into the pear trees by the pear psylla under the conditions of this experiment which involved moderate psylla infestations on Bartlett pear trees on Oriental rootstocks, the combination considered susceptible to pear decline.

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AREA NO. 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Insects and mites that attack citrus and subtropical fruits reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase cost of production. There is a continuing need for research to secure biological and ecological information on these pests that will provide a better basis for the development and implementation of insect control methods than that now available, or suggest additional non-chemical approaches to their control. Additional research is needed on biological control agents, including parasites, predators, and pathogens, and on methods for more effectively integrating biological, chemical, and other control measures. Safer, even more effective and economical control procedures that will minimize or avoid objectionable chemical residues and problems associated with residues should be developed. Research on attractants, chemosterilants, sterilization techniques, and genetic methods need increased attention. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires effective low-cost detection methods, processes for destroying insect infestation in fresh fruits and vegetables intended for shipment to uninfested areas, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. This program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando, Fla., and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research and Plant Pest Control Divisions; at Hoboken, N.J., in cooperation with the Plant Quarantine Division; at Mexico City, Mex., in cooperation with the Plant Pest Control Division and with the Direccion General de Sanidad Vegetal of the Mexican Secretaria de Agricultura y Ganaderia, and on the islands of Guam and Rota in cooperation with the Territory of Guam, U.S. Navy, and the Trust Territory of the Pacific Islands.

The Federal scientific effort devoted to research in this area totals 25.7 scientist man-years. Of this number, 5.0 is devoted to basic biology, physiology, and nutrition; 3.7 to insecticidal control; 0.7 to insecticide residue determination; 4.4 to biological control; 5.8 to insect sterility, attractants, and other new approaches to control; 3.9 to insect control treatments for commodities regulated by plant quarantines, 0.8 to insect vectors of diseases; and 1.4 to program leadership.

In addition, Federal support of research in this area under grants and cooperative agreements totals 0.9 scientist man-years. Of this total 0.4 is devoted to basic biology, 0.1 to biological control, and 0.4 to insect attractants.

PL 480 research grants include India (A7-ENT-26), Biology of gall midges affecting mangoes with special reference to extent of damage; India (A7-ENT-35), Biology of gall midges affecting citrus plants with special reference to the extent of damage; Egypt (F4-ENT-9), Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

New PL 480 projects recently initiated include grants for research in India (A7-ENT-47) on biology of gall midges affecting figs with special reference to the extent of damage; and in Israel (A10-ENT-15) on the ecology, biology, and control of the citrus bud mite (Aceria sheldoni, Eriophyidae).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 21.4 professional man-years is devoted to this area of reasearch.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. Monthly infrared aerial photographs of 6 citrus groves taken at the same time as ground surveys clearly demonstrated population buildups of brown soft scale at Weslaco, Tex. Random infrared aerial photographs of other groves also detected developing brown soft scale infestaitons.

Observations on the fecundity of laboratory reared brown soft scale at Weslaco revealed that one group of scale produced crawlers for 151 days when raised on Mexican squash. Production of crawlers started 45 days after attachment and mean production was 16.3 crawlers per female per day. One individual produced a total 2,399 crawlers during the 21 weeks of its life. During one week (11th) this scale produced 431 crawlers.

Honeydew melons, celery, English ivy, and Cienfuegosia sp. proved effective for laboratory rearing of brown soft scale in Texas, thus adding versatility to rearing procedures in scale and parasite studies.

Citrus trees adjacent to cleopatra mandarin and salt cedar windbreaks had lower populations of the brown soft scale than trees farther out in the grove at Weslaco, Tex. Observations with sticky plates also revealed that populations of the brown soft scale and other citrus insects and mites were similarly influenced by windbreaks on the south sides of the groves. Prevailing winds in the Lower Rio Grande Valley are from the southeast.

At Riverside, Calif., male California red scales in free flight were exposed to various extracts of female sex pheromone in competition with groups of 1, 10, and 20 virgin females on a turntable olfactometer. The most active extracts attracted about 70% of the males responding to all the treatments, and the least active attracted only 1 to 2% of all the responding males. The ratio of male response to the 3 groups of females remained relatively stable. The standard curve obtained from male response to different numbers of virgin females was not altered by the competition from pheromone preparations.

In preliminary tests at Riverside to compare mating response of the laboratory strain of California red scale collected over 30 years ago with that of a recently-collected field strain, males of both strains responded similarly to laboratory female pheromone extracts at dosages of 0, 1, 10, 100, and 1,000 µg with 100 µg appearing to be the optimum dosage.

Progress was made at the University of California under a grant for research on the use of supplemental foods to increase populations of mite predators. When the predaceous mite, Amblyseius hibisci (Chant), was fed various combinations and proportions of sucrose, yeast hydrolysate, and phytophagous mites, yeast hydrolysate slightly increased oviposition; however, its excess was detrimental to survival and oviposition. Addition of sucrose to the diet greatly increased oviposition and survival over that of prey alone.

Techniques were developed in research at the University of Hawaii, under a grant, for rearing southern green stinkbug and its most effective tachinid parasite. Seventy percent of the stinkbugs in Keeau orchard, 33 to 60% at Kailua, Kona, and 19% at Capt. Cook orchard on Hawaii were parasitized. Several species of weeds that are attractive to stinkbugs have been found. Up to 18% of macadamia nuts were damaged by stinkbug feeding.

In India (A7-ENT-26) the gall midge, Erosomyia indica Grover, the most destructive species on mangoes, was found to attack the preflowering shoots in addition to the floral buds, axis of inflorescence, and the newly-formed fruit. In a related project (A7-ENT-35) Dasineura citri Grover, the most destructive gall midge of citrus in India, was established as a distinct species. Progress was made in a third project (A7-ENT-47) to identify and determine the biology of gall midges attacking figs in India. In studies with a species described as Udumbaria nainiensis Grover, the 4th instar larval exit was triggered by sudden increases in humidity. The 4th instar larvae were able to live for 12 days submerged in water.

2. Subtropical Fruit Flies. In Hawaii, fruits of 9 of 20 plant species collected during the period of June 1966 to May 1967 were infested with more than one species of fruit flies. Cocona (Solanum topiro) and tomato yielded melon and oriental fruit flies. Mixed infestations of Mediterranean and oriental fruit flies were recovered from coffee, guava, green sapote, peach, rose apple, mango, and papaya.

In Hilo, Hawaii, mating studies, including dissection of females, indicate that at approximately 80° F about 60 minutes in copula are required by

Medflies and 90 minutes for the oriental and melon flies before spermathecae in most females are filled with spermatazoa. Little or no transfer occurs in the first 15 minutes. Several decapitated females retained motile sperm in their spermathecae until dissected 24 to 27 hours later.

At Honolulu, a technique was developed for obtaining eggs for experimental or mass rearing purposes from a large number of individual females in less than one-tenth the time formerly required when eggs were transferred by hand with a brush. For a 24-hour period the mean and maximum rates of egg deposition obtained with the oriental fruit fly, Medfly, and melon fly were 110, 133; 84, 105; and 52, 63, respectively.

Studies at Honolulu showed that the Medfly must have access to sugar soon after emergence, but apparently can do without water for a few days. At 2 to 3 days after emergence, there was 97 to 100% mortality of adults on water diet alone, compared with 2% mortality on sugar alone, and 1 to 2% mortality on diet of sugar plus water. At 5 to 6 days sugar alone gave 18 to 29% mortality, and sugar and water only 5 to 8%. While the adults need water eventually, the critical constituent of the diet for survival is sugar. Dry sugar instead of liquid mixtures may be adequate for sterile flies that emerge in and are released from aerially distributed packages.

At Hilo tests showed that old pupae of the oriental fruit fly, melon fly, and Mediterranean fruit fly can be held in water up to 48 hours without reducing percent emergence or subsequent adult longevity. At 72 hours significant damage to Medfly pupae appeared. During the period in water, development practically ceased and emergence was delayed by the amount of time the pupae were submerged.

At Hilo melon fly traps baited with cue-lure were spaced uniformly over 135 acres at the rate of 1 per 5 acres. About 90,000 sterile melon flies (half males) emerged near the center, 40' from the nearest trap. The earliest male response was at 5 days of age. The peak response occurred at 8 to 11 days at the time most males were reaching sexual maturity. The nearest trap caught no flies and 67% of the total catch appeared in the downwind quadrant confirming earlier evidence that the flies move out from their emergence sites before most of them reach sexual maturity.

In Honolulu conversion from dehydrated carrot powder larval diet to a low-cost diet, consisting of middlings, shorts, sucrose, Torula yeast (developed at the Mexico City Laboratory), Gelgard M, sodium benzoate, Nipagen, HCl, and water, was made in the laboratory for the production of the three species of fruit flies. Nearly 39 million pupae were produced from approximately 60 million eggs. Six liters of the new diet will support 125,000 Medfly eggs and up to 100,000 pupae can be recovered. Unlike with the Medfly and oriental fruit fly, the middling-shorts diet produces a slightly smaller melon fly pupae than the carrot diet. The smaller melon fly will require evaluation in the field for effectiveness in sterile male release programs. Material cost for the production of the Medfly is now approximately $10.00 per million pupae and for oriental and melon flies about $16.00.

A Medfly larval diet, developed in Costa Rica and consisting of milled bagasse, torula yeast, sugar, wheat germ, mold inhibitors, and HCl, was evaluated in Honolulu. When wheat shorts and middlings were substituted for milled bagasse and wheat germ, the diet performed equally well, except for the slightly smaller pupae it produced.

At Mexico City in an experimental rearing medium, wheat middlings and granulated sugar was substituted for half of the dehydrated carrots in the larval rearing medium. Larval recovery was about the same as that from the standard formula and showed promise of reducing costs in mass rearing. Wheat shorts obtained locally are about 1/10 as expensive as the dehydrated carrots.

Weekly releases of 60,000 marked, tepa-sterilized Mexican fruit fly pupae at El Cerro provided information on seasonal fly movement between the release point and El Bebedero, Morelos, 2 to 3 miles apart. Released flies were marked with yellow fluorescent dye as they emerged through treated foam rubber. The high catches of marked flies occurred during the peak of wild fly populations from May to July and from December to March, which may signal the start of seasonal fly dispersal.

Mexican fruit fly production in a navel orange orchard of 44.1 acres at Coatepec, Veracruz, for the month of November 1966 was about 62,205.

B. Insecticidal and Cultural Control

1. Citrus Insects and Mites. Application of 10% granular UC-21149 to potted citrus at Weslaco, Tex., suppressed brown soft scale up to 17 weeks. Populations on trees treated with 2-, 3-, and 4-gm dosages never reached the level of that on the check tree, which died 25 weeks after the test was started. No evidence of phytotoxicity was apparent from any of the treatments.

A caged citrus tree at Weslaco which was treated with 10% UC-21149 granules showed sharp reductions in brown soft scale (99.5%), purple scale (96.5%), California red scale (85.5%), and chaff scale (90.5%) populations 3 months after treatment. Populations of all 4 species remained at the reduced levels 6 months after they were treated. Parasites remained active in the California red scale and chaff scale populations throughout the observation period.

Applications of methyl parathion at 1/4 lb per 100 gal of water on potted citrus trees increased brown soft scale populations by 69% over the untreated check 10 weeks after treatment at Weslaco. Potted trees treated with methyl parathion at 1 lb per 100 gal produced about the same number of scales as the check, while those treated with 10 ppm of 4,6-dinitro-o-cresol had only 75% as many scales at 10 weeks. Azinphosmethyl and carbaryl, each at 1 lb actual per 100 gal of water, reduced scale 100% and 99.7%, respectively, the second week after treatment. The rapid increase in scale numbers on trees treated with methyl parathion (1/4-lb dosage) demonstrates a

stimulatory effect which first became evident in large scale field tests. These greenhouse studies conducted in the absence of parasites or predators demonstrate that the increases in scale numbers above the check are not related to the suppression of entomophagous species.

In studies at Riverside, Calif., to determine the influence of UC-21149 on the growth and fruiting of young citrus trees by controlling aphids, citrus thrips, and citrus red mite, navel and Valencia oranges and Lisbon lemon trees received 1.25 and 4.5 g active ingredient per tree of UC-21149 in 10% granular formulation, in the water basin a week after planting in April 1966. Eight months after application, the higher dosage produced 100, 99, and 62% control of the spirea aphid on navels, Valencia, and lemons, respectively. Eleven months after application, the higher dosage produced 99, 98, and 89% control of the citrus red mite on navels, Valencia, and lemons, respectively. For the second annual application, 2.5 and 10 g active ingredient per tree was distributed in the water basin on March 1967. Three months later, 88 to 100% control of citrus red mites and 92 to 100% control of citrus thrips was obtained with both dosages in all 3 varieties. UC-21149-treated orange trees were noticeably larger and more vigorous than untreated controls and appeared slightly larger than the trees receiving the foliar application of recommended pesticides. No differences were apparent in the lemon trees.

In other California tests, UC-21149 was applied as a 10% granular formulation in a narrow band in the soil on each side of mature navel orange trees at rates of 0.1 and 0.2 lb active ingredient per tree. During the first one-half year following application, control of citrus red mite was inadequate with only 62% control being obtained with the higher dosage in 5 months. Mite control improved with time, and at 13 months 69 and 96% control was obtained with the 0.1 and 0.2 lb dosages, respectively.

At Orlando, Fla., soil applications of UC-21149 at 1 or 2 oz of granules per inch of trunk diameter controlled citrus rust mites and citrus red mites through 12 weeks and showed no signs of failing.

2. Subtropical Fruit Flies. Bioassay studies with Mexican fruit flies at Weslaco, Tex., showed that the 1:4 technical malathion-PIB-7 formulation used in the Brownsville Mediterranean fruit fly eradication program was residually effective for 9 days under southern Texas climatic conditions. Deposits from aerial applications on citrus, oleander, and bougainvillea foliage showed evidence of slight variation in comparative performance on leaves of these plants.

Examinations of the spermathecae of the last six female Mediterranean fruit flies collected in Brownsville revealed that only one contained sperm. This fly, which was trapped 26 days after the first Medfly found, was the last fertilized female collected and demonstrates the effectiveness of the bait spray applications in Brownsville.

Technical malathion-PIB-7 at ratios of 1:4; 1:20, 1:100; 1:1,000; and 1:10,000 without water were tested as bait spray (1 ml to foliage over

traps) against the Mexican fruit fly. The 1:4, 1:20, and 1:100 formulation attracted and killed the same number of flies at 1, 6, and 14 days after application.

Bait sprays with technical malathion-PIB-7 (1:4) against the Mexican fruit fly were started in January 1967 in 31 acres of navel orange trees at La Orduna, near Coatepec, Veracruz, in the center of a very extensive citrus area. The sprays were applied weekly with a standard Hudson knapsack sprayer to every other tree (alternated each week) whenever possible at the rate of 1.31 oz/acre of technical malathion or 6.70 oz of mixed spray per acre. The 7.2-acre check grove is separated from the 5.6-acre test grove by 8 rows of trees. Collections from 50 traps placed once a month on every other tree in the center of the treated and check areas for a period of 1 week showed a decrease of 84 to 98% in Mexican fruit fly population in the test area over that in the check. Fruit fly infestations per kilo of samples collected in May from tree and ground fruits were reduced by 86.2% and 96.2%, respectively, as compared with the check fruit.

In laboratory tests at Honolulu, Hawaii, small droplets of mixtures of 1 part 95% technical malathion or naled with 8 parts PIB-7 blistered or pitted acrylic and nitrocellulose lacquer and acrylic enamel automobile finishes after 1 hour exposure in sunlight. Mixtures of 0.1 part malathion or naled in 8 parts bait, however, left only light stains easily removable with a mild liquid cleaner, even after exposures of 4 hours.

The laboratory strain of melon flies, bred since 1958 at Honolulu, on artificial non-toxic media, was found to have become highly resistant to standard DDT topical treatments (1 microliter acetone solution applied to the dorsal thorax) without selection with DDT. Applications made up to the limit of solubility in each instance failed to produce significant mortality. The resistance was less when treatment was applied on other body parts. In evaluations prior to 1959, the melon fly appeared only a little more tolerant of DDT than the other Hawaiian species. Both the present oriental fruit fly and melon fly laboratory strains showed a 4-fold increase in resistance to chlordane, but the Medfly showed no change. No increase in resistance to malathion has occurred in any of the 3 species during the past 13 years. Wild melon flies, collected on the island of Hawaii, were also found to now be highly resistant to DDT applied topically to the dorsal thorax, i.e. no LD-50 or LD-95 could be achieved with saturated solutions.

C. Insecticide Residue Determinations

1. Citrus Insects and Mites. At Riverside, Calif., UC-21149 was applied to the soil around orange trees at rates of 0.09, 0.45, and 2.26 g of active ingredient per square foot. Analysis by Pesticide Chemicals Research Branch chemists at Yakima, Wash., of the orange peel and pulp approximately 100 days after treatment showed no UC-21149 residues present. However, residues of the sulfoxide of UC-21149 in the peel from the 3 treatments were 0.06, 1.39, and 12.75 ppm, respectively, and the residues in the pulp were 0.03,

0.35, and 2.63 ppm. Residues of the sulfone of UC-21149 in the peel were 0.01, 0.36, and 2.24 ppm, and those in the pulp were less than 0.01, 0.13, and 0.58 ppm.

2. Subtropical Fruit Flies. In Honolulu, Hawaii, residues of malathion on tomatoes were 0.12, 0.16, and 0.36 ppm after 0, 1, and 3 days, respectively, from air application of an ultra low volume bait spray mixture of 1 part 95% technical malathion and 4 parts Protein Insecticide Bait No. 7 at a rate of 4 oz toxicant per acre.

In Honolulu inorganic bromide residues in papayas packaged in fiberboard boxes were 11.3 ppm at 1 day and 13.1 ppm at 3 days after fumigation at 70° F with methyl bromide for 3 hours at the dose of 2 lbs/1,000 ft^3 and refrigeration at 55° F after 2 hours of aeration. The residues were 17.5 ppm at 1 day and 15.0 ppm at 3 days after fumigation at 4 lbs/1,000 ft^3 for 3 hours at 70° F. Methyl bromide was not detected at the dose of 4 lbs.

3. Analytical Equipment. A method was developed at Hoboken, N.J., for field-checking the calibration of thermal conductivity gas analyzers. At 68° F or above, a small amount of carbon tetrachloride, accurately measured in a hypodermic syringe, is added to a 1-gal jug. After a 2-hr waiting period to insure complete vaporization, the maximum reading is determined on the thermal conductivity unit. The quantity of carbon tetrachloride added to obtain a given reading varies with temperature.

D. Biological Control

1. Citrus Insects and Mites. Observations on parasitism of brown soft scale at Weslaco, Tex., revealed that parasite population trends generally followed the pattern of the previous year. Coccophagus lycimnia again constituted in excess of 90% of the parasites collected. The appearance of parasites throughout the cotton spraying season may be related to widespread use of ultra low volume applications of methyl parathion which may cause less drift into citrus groves. A mean of 2.5% of the scale collected in the Rio Grande Valley during the year were found to be parasitized.

Six species of brown soft scale parasites were introduced from California and released in Rio Grande Valley citrus groves and in tree cages during the year. These were: Encyrtus lecaniorum and Metaphycus stanleyi (currently being reared in the insectary), Metaphycus luteolus, Coccophagus cowperi, C. scutellaris, and Diversinervus elegans. First generation offspring of E. lecaniorum and M. luteolus were recovered but to date no additional recoveries of the introduced species have been made.

Laboratory studies at Orlando, Fla., showed that the citrus red mite virus can be transmitted to the Texas citrus mite. Efficiency of the virus against the latter was equal to that against the citrus red mite. Transmission tests against the citrus rust mite were negative.

In temperature studies at Orlando the entomogenous fungus, Entomophthora floridana, survived for 168 hours at a temperature of -20.5° C. When Texas citrus mites killed by E. floridana were held in the freezing compartment of a refrigerator and later removed and placed in a favorable environment, the fungus formed conidial haloes around the mite bodies. Diseased dead mites subjected to temperatures of from -2.2° C to 0° C for 7 hours, followed by 17 hours at temperatures of from 3.3° C to 6.7° C also produced normal conidial haloes. Texas citrus mites placed in contact with conidia from these tests became infected with the fungus, indicating that the pathogen can tolerate low temperatures.

Aphytis holoxanthus, a species introduced a few years ago, has practically replaced Pseudhomalopoda prima as the dominant parasite of the Florida red scale and is holding scale populations at extremely low levels. A survey of 104 commercial citrus groves throughout the citrus producing area of Florida from February 20 to June 8, 1967, showed that Florida red scale did not occur in economic numbers in any of the groves sampled. Formerly, this pest was the number 2 armored scale problem in Florida.

In tests at Riverside, Calif., to determine residual persistence of the citrus red mite virus, the pathogen remained infective to healthy mites for 28 days on lemon fruits that had been fed on for 24 hours by infected mites. Over 60% infection occurred in mites feeding on the inoculated fruit during the first 8 days; the virus was transmitted for 28 days.

In other tests, pH and salt concentration were shown to play an important part in inactivation of virus suspensions. Inactivation was proportional to salt concentration under neutral and alkaline conditions, but no effect from salt concentration occurred under acidic conditions.

The noninclusion virus of the citrus red mite was further evaluated in the field at Riverside and vicinity through modifications in application and closer scrutiny of mites after application. Buffered and unbuffered distilled water suspensions (0.1%) of triturated diseased mites, both at pH 6, were sprayed onto infested orange trees. During the 2 months following treatment, the incidence of diseased mites on trees sprayed with the buffered suspension was 5 times greater than in the untreated controls and 3 times greater on those sprayed with the unbuffered suspension than in the controls. Applications of virus sprays to mite-infested trees in the morning or after sundown to determine possible ultraviolet inactivation of virus showed no difference in infection and both produced 6 times greater incidence of disease than the untreated controls during the 6 weeks following application. Laboratory reared, virus-infected citrus red mites were released on lemon trees and compared with transfer of field-infected mites from an epizootic. During the next 3 months, the incidence of disease was 8 and 21 times greater in trees receiving the laboratory reared and infected mites and those receiving the field-infected mites, respectively, than in the untreated controls. All tests resulted in eventual epizootics with the incidence of disease in the controls and nontest trees becoming as high as the treatments.

2. Subtropical Fruit Flies. Three species of parasites were recovered from pupae of the Caribbean fruit fly, Anastrepha suspensa, at the University of Florida in studies under a grant. These included Pachycrepoideus vindemiae (Rond.) and Opius sp. The third species has not been identified. An anthocorid, Xylocoris galactinus (Fieber) was observed feeding on fruit fly larvae.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Citrus Insects and Mites. Olfactometer studies at Riverside, Calif., showed that California red scale sex pheromone extracts from a homogenate of 180,000 females contained 0.19 equivalents of attractiveness when compared with live virgin females. By contrast, extracts from a cold trap condensate representing pheromone from 62,500 source females (1×10^6 female day equivalents) contained 1.34 equivalents of attractiveness. The yield of the latter was 7 times that of the whole body extractions.

Female sex pheromone of the California red scale collected as a cold-trap condensate and as extracts of homogenized whole females at Riverside are being shipped to the Natural Products Investigations Unit of Pesticide Chemicals Research Branch, Beltsivlle, Md., for purification, identification, and eventual synthesis of the pheromone. Of the fractions returned to Riverside and bioassayed for male response, 3 were highly attractive and their properties indicate the pheromone to be an unsaturated ester containing at least 2 double bonds.

At Riverside a pooled ethereal extract of the California red scale female sex pheromone obtained from a cold-trap condensate and homogenized whole females was placed in a shallow dish of sand and exposed to males in free flight after various intervals to determine residual activity. A 1,000 µg dosage remained as attractive as 10 virgin females for 2 weeks and still retained some activity after 34 days. The lipids in the extract derived from the homogenized females are believed to be acting as extenders. Myverol a monoglyceride of lard, acted as an extender of an extract of cold trap condensate alone.

In studies undertaken at Weslaco, Tex., to sterilize brown soft scale by irradiation as a medium for releasing parasites in citrus groves without adding to the biotic potential of the natural scale population, the age at which the scales were irradiated was critical in inhibiting reproduction in this parthenogenetic species. Irradiation of either sexually mature or 25-day-old scales severely limited but failed to stop crawler production. Scales that were irradiated at an earlier stage of development produced no crawlers at dosages of 20,000 and 40,000 r in a previous test. Since scale populations do not develop uniformly, the precise timing of the irradiation treatment required to provide complete suppression of crawler production is difficult to accomplish.

2. Subtropical Fruit Flies. Fourteen of 17 materials screened for attractancy to the fruit fly, Anastrepha suspensa, in Miami, Fla., were equal to casein hydrolysate when tested on sticky board traps. Glass traps with liquid protein hydrolysate baits were significantly more effective in trapping A. suspensa than were sticky traps baited with protein hydrolysates.

In Hawaii 3 methods of distributing trimedlure-dibrom were evaluated on non-replicated 1/4 x 1/4 mile plots in tests against male Mediterranean fruit flies where sterile flies had been released twice weekly in the sea-level area to obtain uniform populations under high temperature conditions. Three biweekly liquid aerial applications in lines 300' apart resulted in reductions in male trap catches of from 89 to 98% one day after application, but generally lost effectiveness within 5 days. Eighty 2" x 2" bait stations added 3 times at 3-week intervals (1 per 2 acres) gave reduction of 73 to 95% at 5 to 15 days after the first 2 applications. Saturated small wafers, totaling 12 per acre in 3 biweekly applications, gave reductions of 56 to 93% at 1 to 5 days after application. In the third and fourth weeks after the 3 applications of each treatment, catches per trap day averaged 48, 3, and 6, respectively, for liquid aerial applications, bait stations, and wafers.

In Hawaii, male, lure-toxicant formulas and methods of exposure were continued using replicated trays usually suspended under treated foliage or bait stations. Trimedlure-saturated wafers exposed 100 days on shaded soil were equal to freshly saturated wafers when suspended as bait stations. Bait stations or cane-fiber board wafers saturated with trimedlure killed 5 times as many flies for 2 months when suspended in the open over trays as when lying on the ground where flies were subject to ant predation.

A cooperative effort, supported jointly by the Honolulu station, U.S. Air Force, and Portugese Azores, was undertaken on the 240 mi^2 island of Terceira to complete a feasibility trial of trimedlure-naled applications for control of the Medfly by the male annihilation method. Aerial applications at the rate of 5 lb of the lure formulation/km^2 containing 5.75% CAB-O-SIL, 5% naled, and 89.25% medlure or trimedlure were first used. Bait stations, made of 2 x 2 x 1/2" cane fiberboard squares, saturated with the lure-toxicant mixture were interspersed at the rate of 3,500 per month for 3 months with the foliar treatments and later replaced some of them. Male catches were substantially reduced in all treated host areas.

Tests were continued in Honolulu to improve the residual effectiveness of foliage deposits of male lure-toxicant-thickener mixtures, particularly those containing trimedlure, which usually become ineffective within 3 or 4 days. Preliminary tests in which different thickening agents and toxicant formulations were used with trimedlure, indicate that deposits containing naled CS-5891 and Myverol 1800 may be effective up to 2 weeks.

Approximately 4 and 6 million sterile melon flies were shipped from Honolulu to Rota, Mariana Islands, between September 15 and November 24, 1966, and between March 30 and July 6, 1967, respectively, to eradicate

the fourth and fifth reintroductions of the melon fly from Guam. Nearly half of the 1967 shipments were of a dark, easily identifiable strain sent for field evaluation. It was recovered in survey traps at only half the rate of the 10-year-old standard laboratory strain.

In Hawaii, newly emerged female Medflies irradiated at minimum doses of 5 and 7.5 Kr, then paired with normal males, did not lay any eggs, but 6-day-old virgin or non-virgin females treated similarly laid many nonviable eggs. At the 7.5 Kr dosage, a mean hatch of 2% was obtained from pairings of normal females with males irradiated shortly after emergence, whereas 0.1 and 0% mean hatch figures were obtained from normal females paired with males irradiated as 6-day-old mated and 6-day-old unmated flies, respectively.

In Honolulu tepa-sterilized flies were more resistant to topical applications of malathion than normal flies. The amount of malathion required to achieve the LD-50 level of mortality was increased 1.38, 1.72, and 2.37 times, and for the LD-95 level, 1.30, 1.62, and 2.28 times in the tests with chemo-sterilized oriental, melon, and Mediterranean fruit flies, respectively, compared with normal flies. Further tests indicated that all three species, when sterilized by ionizing radiation, also became more resistant to malathion and to a greater extent than those sterilized with tepa. For example, at the 50% mortality level, the oriental fruit fly required 1.71, the melon fly 1.71, and the Medfly 2.23 times as much malathion when sterilized by ionizing radiation, respectively, as untreated flies. At the 50% mortality level, the oriental fruit fly required 3.95 and 8.35, and the Med-fly 2.35 and 3.38 times as much DDT when sterilized by tepa or ionizing radiation, respectively, as untreated, non-sterile flies.

No adverse effects from the use of Day-glo fluorescent powders as compared to Calco oil soluble dyes for marking released flies were found in tests at Honolulu. The oriental fruit fly, the Medfly, and the melon fly were marked with Day-glo fluorescent powders Rocket red, Signal green, and Horizon blue, and the Calco blue (RA) standard. Possible adverse effects were determined by comparing survival rates for 4 weeks. Studies of dye transfer from marked to unmarked tephritids caught together in dry traps have shown that this hazard is negligible under field conditions. No difference in mortality rates occurred in the first 3 weeks after emergence.

Paper bags (12-lb) containing excelsior and food (such as are being used in a Medfly eradication program in Central America as a means of aerially dispersing Medflies allowed to emerge inside) were tested at Honolulu for their effect on the flies. Placement of food on the excelsior reduced mean survival rates 3 weeks after release nearly 50% compared to food placed on the wicks. Loading rates affected mutilation. It ranged from 2.5% in controls to 4, 6, and 8% at 2,500; 5,000; and 10,000 loading rates, respectively. Survival at the 10,000 rate at 3 weeks averaged 21% compared to 38% at the 2,500 rate. CO_2 concentrations reach 10x normal.

In Honolulu, 15 samples of trimedlure-extender mixtures, prepared by the chemists at Beltsville, were tested on wicks to determine increased persistence of attraction as compared with trimedlure alone. None of the samples tested enhanced the degree of attractancy of trimedlure, nor was there any depression. However, all extended the duration of attration at least 20% over that of trimedlure with no additive.

Standard trimedlure traps in a 15-replicate experiment, exposed at various heights, caught significantly more flies (70 to 80%) at 15' than at the 0.1 and 2 ft levels. The catch at 15' was 30% greater than at 6', but this difference was not statistically significant.

In a field test in the state of Morelos, Mexico, releases of sterilized, well-fed adult Mexican fruit flies which had been allowed to emerge in the laboratory, consistently showed a higher incidence of mated females when examined microscopically than flies which had been released as pupae from pupal release stations. It is possible that the laboratory feeding may help the flies released as adults to attain sexual maturity sooner than those released as pupae when conditions in the field are not optimal. Preliminary data indicate that at certain seasons of the year when conditions are better, the flies from both adult and pupal releases will attain sexual maturity at about the same time and show about the same incidence of mated females.

At Mexico City, flies from pupae treated with a sterilizing dosage of tepa (5% for 1 minute) were forced to emerge through a 1.5 capping of grated foam rubber impregnated with an 8% concentration of dye. Results showed some loss of sterilizing effect in both males and females.

In olfactometer tests of 125 ENT candidate attractants at Mexico City, one proteinaceous material and three Sargentia greggii fruit extracts attracted the same number of Mexican fruit flies as the standard. Sixty-eight other compounds attracted flies but to a lesser extent than the standard cottonseed hydrolysate.

Of 158 candidate lures field-tested in McPhail traps in the state of Morelos, 2 ENT candidates, a Sargentia greggii extract and a terpene of grapefruit oil, were about 1.5 times more attractive than the standard cottonseed hydrolysate-borax lure in pellet form (Class 5). Twenty-four compounds were 0.25 to 1.00 as attractive as the standard (Class 1 to 4) and 131 attracted no flies.

An enzyme hydrolyzed meat protein fermentation nutrient (O.M. HAP) was 65% more attractive than cottonseed hydrolysate-borax pellets (0.20:1) when tested in solution at 2% with 2% borax. A disadvantage of this material is that it attracted 2.9 times more muscid flies than the standard.

Three replicates of 1, 2, 4, 8, and 12 traps baited with cottonseed hydrolysate borax pellets were exposed in mango trees for 5 days to determine the number of traps per tree needed to capture the maximum number of

flies. The results indicated that more than 12 traps can be used, and that there may be little or no competition between traps.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. In Honolulu, Hawaii, the minimum period of post-treatment refrigeration at fruit temperatures of 45° and 55° F were determined with infested papayas for fumigations at 70 ± 1° with methyl bromide. The dose was 2 lb/1,000 ft^3 for a 35-lb load of fiberboard boxes with shredded paper excelsior that occupied 44 ft^3 in the 100 ft^3 chamber. There were no survivors for the 3-hr fumigation treatment followed by 3 days at 45° or 6 days at 55°

In Honolulu, the hot water dip for controlling decay organisms reduced the survival of eggs and larvae of the oriental fruit fly from papayas that were fumigated with methyl bromide for 2 hours at 70 ± 1° F at the dose of 1 lb/ 1,000 ft^3 when the dip treatment was given before or after the fumigation. There were no significant differences between fruits that were treated while hot and those that were cooled to 70° before treatment. There were no significant effects from fumigation with ethylene dibromide at the doses of 4 and 8 oz/1,000 ft^3 for 2 hours.

In Honolulu the development of 2- to 5-hour-old eggs and mature third-instar larvae of the oriental fruit fly were arrested after treatment in hot water. The minimum treatment periods for the eggs were 60 minutes at 110°, 14 minutes at 115°, 3 minutes at 120°, and 0.25 minute at 130° F.

In Honolulu the minimum treatment periods with hot water found effective for mature larvae of the oriental fruit fly in tomatoes were also effective in limited testing with melon fly infestations at pulp temperatures of 110°, 115°, and 120° F. Forty-five to 115 minutes were required to raise the pulp temperature from 70° to treatment temperature. Treatments with temperature run-up to 120° only killed most of the infestations but when the run-up was supplemented with the minimum treatment of 5 minutes at 120°, there were no survivors.

At Mexico City, mangoes infested with Mexican fruit fly were maintained for 3 and 6 days at 35° F. and then fumigated with 2 lb of methyl bromide/1,000 ft^3 for 2 and 3 hours at 34°, 35°, and 40° F. Mortality varied from 63 to 93%; the optimum treatment was 6 days at 35° F. followed by 3 hours of fumigation at 34° F. Mangoes did not tolerate methyl bromide well. Whether this injury was due to the small amount (2%) of chloropicrin in the fumigant was not determined.

Treatment of infested mangoes with 125 tablets of Phostoxin (aluminum phosphide 70%, ammonium carbamate 26%, and other ingredients 4%)/1,000 ft^3 required about 4 days exposure at 70° F. to obtain 100% mortality. At 1 and 2 days exposure the mortality was 95.4 and 99.4%, respectively. At these dosages and exposure periods the fruit were injured.

Larvae of Anastrepha serpentina in the first to second instar in carrot medium were completely killed with 8 oz of ethylene dibromide/1,000 ft^3 at 75° F. Third instar larvae, naked and in carrot medium were killed with 16 oz of ethylene dibromide/1,000 ft^3 at 75° F.

Infestations of the Mexican fruit fly in mangoes were fumigated at 70° F with methyl bromide alone and mixed with ethylene dibromide. The mortalities for methyl bromide varied from 2.7 to 87.6%. Mortalities for mixtures of methyl bromide and ethylene dibromide were approximately the same as for ethylene dibromide alone. Methyl bromide above 8 oz injured mangoes severely. Whether injury was due to the 2% of chloropicrin included in the methyl bromide was not determined. To kill 100% (probit 9) of naked full grown larvae required 16 oz of methyl bromide and 2 oz of ethylene dibromide.

2. Other Insects. In preliminary tests at Hoboken, N.J., fumigation with 270 aluminum phosphide pellets per 1,000 ft^3 for 72 hr at 80° F or above failed to give 100% control of Megastigmus spp. larvae in Picea seeds. Small numbers of Plemeliella abietina larvae were killed at this dosage. In other tests, seeds of Picea abies, P. sitchensis, Pinus mugo, and P. sylvestris showed no injury when germinated shortly after fumigation at this dosage.

Fumigation in a saturated atmosphere of carbon tetrachloride (near 58 lb/ 1,000 ft^3) at Hoboken caused severe injury to seeds of Pinus mugo and Picea glauca, even with exposure shortened to 4 hr. In other tests Pinus pinea and Cedrus deodara seeds were injured by 8- and 16-hr exposures.

At Hoboken germination tests shortly after fumigation with Vertifume (carbon tetrachloride-carbon disulfide, 5:1 by weight) at a dosage of 30 lb/ 1,000 ft^3 of the carbon tetrachloride for 24 hr indicated no injury to seeds of Pinus nigra and Picea abies. Some reduction in germination occurred with Picea sitchensis, P. glauca, and Pinus mugo. In other tests, seeds of Pinus caribaea and 2 species of Cupressus tolerated fumigation with 2 lb/1,000 ft^3 of hydrogen cyanide for 72 hr atmospheric pressure, or 24 hr at 25-inch sustained vacuum; Cedrus deodara was apparently injured.

In studies at Hoboken the rate of aeration of residual concentration of methyl bromide from the center of 100-lb bags of conifer seeds was not substantially increased by insertion of several perforated pipes through a bag of Pinus nigra seeds.

At Hoboken in cooperation with the Chilean Government, 4 varieties of grapes fumigated with methyl bromide in Chile, then cold treated enroute to the United States, were found tolerant to the dual treatment. Heretofore, the fumigation had been made following arrival at U.S. ports. In other tests, Rosaki grapes from Greece were found to tolerate fumigation after an intransit cold treatment. Previously it had been indicated that Spanish Almeria grapes, although not affected by fumigation, apparently would not tolerate lengthy storage.

At Hoboken hydrogen cyanide fumigation with 4 lb/1,000 ft^3 for 4 hr, atmospheric pressure, at 72° F apparently caused no adverse effects to imported wool samples. Fumigation with methyl bromide at an equivalent rate for khapra beetle control occasionally leaves a residual odor in wet wool. Ethylene oxide-carbon dioxide mixture (10:90) at a rate of 35 lb/1,000 ft^3 for 72 hr also had no observable effects on the wool.

Bruchus rufimanus survived in faba beans at Hoboken following atmospheric fumigation with methyl bromide 4 lb/1,000 ft^3 for 4 hr at 82° F, 6 hr at 72°, or 8 hr at 52°. Previously it had been considered that 3 lb for 4 hr at near 72° was effective. Fumigation in a 25-inch, sustained vacuum, with 3 lb for 2.5 hr at 70° or above continued to be effective. In preliminary tests, Caryedon gonagra in Cassia seeds survived atmospheric fumigation with 3 lb for 3.5 hr at near 85°, indicating that other species of bruchids are resistant to atmospheric schedules with methyl bromide.

At Hoboken small numbers of adults of a wood boring bostrichid, Sinoxylon sp., from India were killed by methyl bromide 2 lb/1,000 ft^3 for 16 hr atmospheric pressure at 70° F or 4 lb for 4 hr at a 15-inch sustained vacuum at 43° F. This indicates that the slightly higher schedules currently in use for other wood boring insects would be effective.

In small-scale tests at Hoboken, adults of a darkling beetle, Blapstinus sp., from California survived 2 hr atmospheric fumigation with methyl bromide 4 lb/1,000 ft^3 at 40 to 42° F, or 3 lb at 51 to 53°. Survival occurred with concentration-time products above those recommended for use with Chilean melons or other commodities occasionally found infested with a related species.

In preliminary studies at Hoboken an undetermined variety of strawberries tolerated fumigation with methyl bromide 3 lb/1,000 ft^3 for 2 hr at near 70° F or 3.5 hr at 42°.

I. Insect Vectors of Diseases

1. Citrus Insects and Mites. Further tests with tristeza virus in Florida showed that the disease has continued to spread slowly but steadily. In a grove where 18 mature citrus trees had been inoculated artifically, field populations of aphids transmitted the virus to 6 of 38 Key lime indicator plants within the grove during a 4-year period.

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AREA NO. 5. FORAGE AND RANGE INSECTS

Problem. Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, seed chalcids, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varities which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., and Mesa, Ariz., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Gulfport, Miss. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Research on clover and turf grass insects at Corvallis, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues is conducted at Beltsville, Md., Tifton, Ga., and Yakima, Wash., in cooperation with the Washington Experiment Station. Studies on varietal resistance, insect vectors of

plant diseases, and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects: W-37 (Natural factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), and S-55 (Alfalfa Insects).

Three contracts, 11 grants, and 2 cooperative agreements with State Universities and Experiment Stations will provide additional research on insect biology, physiology, and nutrition, biological control, attractants, and varietal resistance.

The Federal scientific effort devoted to research in this area totals 21.5 scientist man-years. Of this number 3.5 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 2.2 to insecticide residue determinations, 4.0 to biological control, 0.6 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 4.1 to varietal evaluation for insect resistance, 0.2 to insect vectors of diseases, and 1.4 to program leadership.

In addition Federal support of research in this area under contracts and grants provides a total of 4.3 scientist man-years. Of this total 1.0 is devoted to basic biology, physiology, and nutrition, 1.0 to biological control, 0.4 to insect attractants and other new methods of control, and 1.9 to varietal evaluation of insect resistance.

Two P.L. 480 projects are underway: E21-ENT-9, "Insect Vectors of Virus Diseases of Various Forage Legumes" with the Research Insitute of Plant Protection, Poznan, Poland, completed January 1967, and A10-ENT-6, "Acoustic Responses of the Desert Locust (Schistocerca gregaria Forsk.), Moroccan Locust (Diciostarus maroccanus Thbg.), and Acrotylus insubricus Scop. (Orthoptera, Acrididae)" with the Hebrew University of Jerusalem Jerusalem, Israel.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 46.6 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

1. Grasshoppers. Ecological studies on grasshoppers in relation to plant damage were continued in 1967 on rangelands in central and southeastern Arizona. Hatching of spring-group grasshoppers began earlier than normal, and populations were higher than in 1966, due chiefly to the warm and dry fall weather in 1966 that extended the egg laying period of female adults.

Densities declined by late June owing to both a dispersal of late instar nymphs and adults and dry food plant conditions.

Studies on plant damage by grasshoppers on the San Carlos Reservation were continued on two 20-acre range plots and a 3200-acre fenced enclosure. Each 20-acre plot is subdivided into two fenced and two unfenced plots. Since 1956 insecticide applications have been made with ground equipment as needed to give effective season-long control of grasshoppers on one-half of each plot. The average square yard grasshopper numbers for the period April-July 1966 in untreated fenced and grazed plots were 1.9 and 2.2, respectively. Loss of weedy and grass herbage in spring was negligible due to an abundance of plants. By July 14 percentages of grass eaten by one 'hopper per square yard in the fenced plot with a grass cover of 21.1% were 7.6% on blue grama, 10.9 on curly mesquite, and 11.1 on squirrel-tail. In local areas having low populations of grasshoppers, scattered squirrel-tail plants were completely defoliated and a lack of blade growth in spring 1967 indicated that these plants were dead. In 1967 damage to grass blades by low numbers of grasshoppers is much greater than in 1966 due to the short growth of grass and a lack of weedy grasshopper food plants.

Preliminary data at Bozeman, Mont., show that the grasshopper, Melanoplus brunneri, often found in high altitudes mountain meadows, appears to pass through two consecutive winters in the egg stage. Eggs were collected from two locations during the summer of 1966 and various handling methods were attempted to induce hatching, but only partial success was achieved.

At Manhattan, Kans., under a grant to Kansas State to study the food plants of grasshoppers on rangeland versus cultivated pastures, it was shown that grasshoppers appeared earlier and developed more rapidly in cultivated pastures than on rangeland.

Research in Israel under P.L. 480 Project A10-ENT-6 showed that when masticating sounds of the desert locust were recorded and played back to nymphs a response to food occurred. Two types of sound were produced by Moroccan locust, one with a definite rhythm produced only by males and one with no discernable rhythm produced by both sexes. Stridulatory sounds were produced only during daylight hours.

2. Alfalfa Insects. Recent laboratory studies at Lincoln, Nebr., have demonstrated conclusively that two strains of the spotted alfalfa aphid exist which differ in their ability to produce sexual forms when subjected to the proper environmental conditions. By periodically subjecting field collected aphids to the conditions which cause formation of sexuales, it was demonstrated that from May through July, 1966, 100% of the population sampled near Lincoln was of the sexual or holocyclic strain. Aphids (heterocyclic strain) incapable of producing sexuales were not collected until late August and were probably migrants from more southern areas. The two strains appeared to occur more or less in equal numbers in the field population from late September until aphid activity ceased.

At Mesa, Ariz., eight environmental chambers were programmed using four temperature regimes (40, 55, 70, 85° F) and two day-length cycles (8 and 16 hours). Adult alfalfa seed chalcids were caged on excised racemes and allowed to oviposit for periods up to 48 hours prior to exposure in chambers. Results showed that 8 hours of light per day at all temperature regimes did not produce an adequate infestation to detect diapausing larvae. At the 16-hour day-length cycle a high percentage of diapausing larvae were produced at all temperature regimes except 40°. Nearly one-third of the infested seeds had diapausing larvae but there were no differences in percent of larvae in diapause among different temperatures.

In studies at Mesa, Ariz., field populations of the alfalfa seed chalcid entered larval diapause on August 31 when the photoperiod was 12 hours and 54 minutes. At that time only one percent of the population had entered diapause. Following that date diapausing larvae increased at a rate of 10% a week until October 26 when 90% of the population had entered diapause. Termination of field diapause occurred during late May when less than 5% of the larvae were in diapause. The photoperiod was slightly less than 14 hours, although temperature is believed to be the primary factor terminating diapause.

In greenhouse tests at Mesa, Ariz., over 75% of the nymphal and adult populations of lygus bugs died after confinement for three weeks on eight different growth stages of Moapa alfalfa plants. Lygus bugs failed to develop satisfactorily on plants representing growth stages from seedling to bud.

In laboratory tests at Tucson, Ariz., several thousand lygus bugs were successfully reared in captivity on fresh beans treated with solutions of 10% sucrose, 10% honey, or tap water. Although adult mortality was higher on beans treated with solutions of 10% honey, no significant difference in nymphal mortality was observed among beans treated with different sugars or tap water.

At Mesa, Ariz., damage to alfalfa by the Egyptian alfalfa weevil was higher in 1967 than in previous years. Populations of larvae per sweep averaged 4.7 in February, 174.0 in March, and zero in mid-April.

Field plantings of six legumes at Beltsville, Md., to determine their relative suitability as hosts for the alfalfa weevil confirmed previous laboratory studies. Alfalfa was completely defoliated in the spring of 1967; the other legumes sustained minor damage corresponding to larval populations. The number of larvae per square foot for alfalfa was 303, white sweet clover 95, hairyvetch 34, alsike clover 7, ladino clover 4, and red clover 3. A survey of farmers' fields in Maryland supported the above. Ladino clover and hairyvetch were infested by larvae but damage was negligible. Larvae collected from red clover heads and reared for positive identification were 65% lesser clover leaf weevil, Hypera nigritostris, 29% clover head weevil, H. meles, and only 7% alfalfa weevil, H. postica.

In Maryland and New Jersey in 1967, both adult and larval populations of the alfalfa weevil were higher than for the previous year. Larval populations developed early in central Maryland and southern New Jersey, and remained high for nearly a two-month period which was much longer than normal. Populations were relatively light in northern New Jersey. Significant correlations were obtained between numbers of overwintering adults and peak larval populations among individual fields in both States. It seems likely that rough predictions of damage potential can be made on the basis of winter surveys for adults. The decline of adults from November to March has been roughly the same each year varying from 58.5% to 66.7%.

At Beltsville, Md., the normal summer diapause of adult alfalfa weevils was effectively terminated by topical application of the synthetic hormone, 10,11-epoxyfarnesenic acid methyl ester. A dosage of 100 µg of the epoxide per weevil invariably resulted in increased activity and feeding within three days and oviposition began in about seven days. Feeding, mating, and oviposition then continued at normal dates. The same response was elicited from weevils in diapause regardless of their age. On several occasions, a parasite, Microctonus sp., emerged from hosts 14 days after treatment. Practical possible uses of the hormone include: (1) continuous rearing in the laboratory of insects that normally diapause in the adult stage, (2) immediate use in the laboratory of adults collected from the field in the diapausing state, (3) control of insects in the field by disrupting their normal life cycle.

A pronounced crowding effect on alfalfa weevil oviposition was demonstrated at Beltsville, Md. Two weevils per pint or gallon container produced nearly twice the number of eggs per female than 20 or more weevils per jar. Also, changing feeding and oviposition sites daily increased oviposition as compared to changing every two or three days. This suggests the presence of an oviposition deterrent being deposited by females at the time of laying eggs.

In June 1967 a cooperative agreement was initiated with the University of North Carolina to determine the effects of alfalfa saponin fractions on the development and feeding behavior of the alfalfa weevil.

In research on the physiology of lygus bug injury under a grant with the University of California, it was shown that when lygus bugs feed for as short a time as four hours on the floral parts of alfalfa, an abscission layer is formed in one to two days and the bud drops off. Preliminary evidence indicates that the abscission factor is of insect origin.

In a grant to New Mexico State University, techniques for feeding aphids through parafilm under sterile conditions were developed. The mineral requirements, particularly trace elements, of the cotton aphid are under study. Lygus bugs have been maintained for one month on an artificial diet. First and second instar nymphs did not mature but third and fourth instar nymphs matured and deposited viable eggs.

3. Clover Insects. In Nebraska in the fall of 1966, a lepidopterous borer, determined as Walshia miscecolorella, was found tunneling in the crown area and killing the top growth of first year plants of both white and yellow-flowered biennial sweetclover. It is presumed to be the same species, reported under the name W. amorphella, which seriously damaged sweetclover in Texas during the early 1950's. Greenhouse studies indicate that the species passes the winter in the later larval instars. Pupation occurred in loosely spun cocoons in the soil. At greenhouse temperatures moths emerge from the cocoons in about 10 days. Eggs are laid singly on the stems of young seedlings about an inch or two above the soil surface. It is possible that only one generation may occur per year. The only serious damage caused by this insect during the 1966 season occurred in sweetclover breeding nurseries in the vicinity of Lincoln. The insect, however, was detected in 5 southeastern counties but not in several northeastern counties.

4. Grass Insects. To determine the damage caused by a bromegrass seed midge, Stenodiplosis bromicola, a pre-harvest head sample was taken from eight southeastern Nebraska bromegrass fields. In one sample of Lincoln bromegrass, 50.4% of the florets contained diapausing larvae. Approximately 25% of the florets from all samples contained diapausing larvae. The average percent of normal seed in all samples was about 34, indicating that a considerable portion of the 1966 seed crop was lost because of the midge.

At University Park, Pa., three grass-feeding leafhoppers, Latalus sayi, Endria inimica and Draeculocephala antica, were reared in the greenhouse on a mixture of timothy, brome, and orchardgrass. A few Dryinid parasites, Chalcogonatopus sp. were maintained on the L. sayi and E. inimica during this time.

At Tifton, Ga., 4, 8, and 16 spittlebug adults, feeding on Coastal bermudagrass in the greenhouse, inhibited root development. Untreated plants produced more than twice as many roots as plants subjected to four spittlebugs per plant and more than five times as many as produced by the other two treatments. Manual defoliation of the grass gave results similar to those obtained with 8 and 16 insects per plant.

5. White-fringed Beetles. At Gulfport, Miss., the survival of newly hatched white-fringed beetle larvae was 89% greater when reared in clay pots than in plastic pots.

In studies at Gulfport, Miss., a diet consisting of 10 gm freeze-dried peanut leaf meal, 5 gm NBC Vitamin fortification, 5 gm agar, 1.0 ml formalin, and 200 ml distilled water, was tested as an adult diet for the white-fringed beetle. Good adult longevity and egg production were obtained.

Under a grant to Auburn University, it was found that mold inhibitors used in artificial diets were lethal to white-fringed beetle larvae. The most successful rearing procedure was to use sprouted Irish potatoes.

B. Insecticidal and Cultural Control

1. Grasshoppers. Field tests were conducted at Bozeman, Mont., to establish effective dosages of insecticides applied by aircraft as ultra low volume sprays to control grasshoppers on rangeland. The indicated dosage for Bay 39007 was 8 oz actual per acre; for Mobil MC-A-600 5 oz, and for diazinon 10 oz.

Two experiments were conducted in Montana with technical malathion applied by aircraft at ultra low volume (8 oz fluid/acre) to control grasshoppers. One compared fine and coarse spray applied from different heights. From a height of 200 feet fine spray was found significantly inferior to coarse spray. There was no significant difference between treatments (1) fine at 50 ft, (2) fine at 100 ft, (3) coarse at 100 ft, and (4) coarse at 200 ft. The spray classed as coarse with a volume median diameter (vmd) of 278 u was recommended over fine spray with a vmd of 135 u. Individual plot data indicated that the coarse spray applied from 100 ft would give the best results under a variety of field conditions. In the second experiment, 0.1 inch of moisture, applied to malathion-treated plots immediately prior to and at intervals of two and eight hours after treatment, showed no signif-cant effect on control. These results were further substantiated by observations on the effect of natural rainfall and dew; however, it is pointed out that field experience has shown that rainfall reduces the effectiveness of malathion.

2. Alfalfa Insects. Twenty-one new candidate insecticides were screened at Beltsville, Md., against adult alfalfa weevils, and five gave lower LC_{50} values than the standard azinphosmethyl. These were fenthion, CIBA C-9643, Hercules 9007, Shell SD-14045, and Vero Beach Bay 77488.

Phorate, parathion, and carbaryl were applied in granular form to five-acre plots of dormant a falfa both in late fall and early spring in central Maryland for alfalfa weevil control. Phorate gave significantly better results than the other two and might provide adequate control in normal years. At the rate of 2 pounds per acre in the fall, weevil adults were reduced about 85% and foliage damage was reduced about 60%. At the rate of 1 lb per acre in the spring, weevil adults were reduced about 89% and foliage damage was reduced about 84%. Niagara NIA-10242 applied to 1/2 acre plots gave 67% (fall application) and 97% (spring application) con-trol based on foliage damage at time of harvest.

A comparison of the commonly recommended insecticides applied to the grow-ing crop showed that methoxychlor (1-1/2 lb per acre) gave better control of weevil larvae than Imidan, parathion, azinphosmethyl, malathion, and carbaryl. However, methoxychlor was significantly better in only one of four comparisons.

At Beltsville, Md., six experimental insecticides applied at comparable dosage rates to small plots gave better control of weevil larvae than the

check, azinphosmethyl. In descending order of effectiveness they were: Niagara NIA-10242, Union Carbide UC-34096, Dursban, CIBA C-9643, Shell SD-14045, and Hercules 13462.

At Lincoln, Nebr., dimethoate, endosulfan, ethion, toxaphene, General Chemical GC-6506, and DDT were tested against the tarnished plant bug, L. lineolaris, and the alfalfa seed chalcid, Bruchophagus roddi. Nymphs of the tarnished plant bug were initially controlled by all the compounds. None of the compounds provided satisfactory initial control of adults. DDT provided the greatest degree of residual control against this species. The alfalfa seed chalcid was not controlled by any of the insecticides. None of the insecticides significantly increased seed yields.

3. Grass Insects. DDT, malathion, and diazinon were evaluated at Lincoln, Nebr., for the control of the bromegrass seed midge. A reduction in the number of adult midges was evidenced only after repeated applications.

At Tifton, Ga., application of insecticides to the soil surface of millet fields killed large numbers of mole crickets, reduced loss of plant stand, and increased yield of forage. Stauffer N-2790 bait, Kepone bait, Stauffer N-2790 granules and/or Mobil MC-A-600 granules, and trichlorfon granules performed best in the order given.

At Tifton mowing Coastal bermudagrass fields infested with two-lined spittlebugs drastically reduced the numbers of nymphal masses and was the best control method for nymphs. Azinphosomethyl and carbaryl at 1.5 kg/ hectare controlled nymphs and adults on Coastal bermudagrass. Malathion, diazinon, and Dibrom at the same rate controlled adults but not nymphs.

4. White-fringed Beetles. Laboratory tests were conducted at Gulfport, Miss., with 18 insecticides as foliar sprays at 1/2, 1, and 2 pounds per acre, to control white-fringed beetle adults. Twenty adult beetles were caged on the foliage after spraying and mortality counts were made after a 48-hour exposure period. Dursban and Bay 78182 were the most promising at all three levels. American Cyanamid 43913 and Shell SD-8280 gave good control at the 1- and 2-pound rate.

Twenty-nine compounds were tested against newly hatched white-fringed beetle larvae. Soil was treated with these compounds at 1, 5, and 10 pounds per acre, placed in flower pots and infested with newly hatched larvae in August. The soil was examined for larvae from November to January. At the 5- and 10-pound rates, isobenzan, nonachlor, mirex, Bay 77488, Dursban, Compound 4072, Stauffer N-2790, and Mobil V-C 3-668 gave control comparable to that of DDT.

White-fringed beetle larvae collected in a treated nursery near Gulfport, Miss., and analyzed by gas chromatography contained DDT and dieldrin. Soil samples taken at the same location also showed the presence of these insecticides. Laboratory reared larvae and field collected larvae from

non-treated areas did not show any insecticides. This might help to develop a quick method of determining resistance to insecticides.

C. Insecticide Residue Determinations

1. Niagara NIA-10242. At Tifton, Ga., plots of silage corn were treated with NIA-10242 wettable powder at rates of 0.25, 0.50, and 1.00 pounds per acre and the corn ensiled the following day. Initial residues of NIA-10242 in corn were about 9.8 ppm. The residues declined in the field, but in silage the level remained rather constant. No phenolic hydrolysis product was detected in the corn from the field or in the silage. No residues of of NIA-10242 or its phenolic hydrolysis product were found in milk from cows fed the treated silage. Cholinesterase activity of the blood from the animals fed the treated silage appeared unaffected.

Initial residues on Coastal bermudagrass treated at Tifton, Ga., with NIA-10242 at 1 pound per acre were 24.1 ppm of NIA-10242 and 0.23 ppm of its phenolic hydrolysis product. After weathering in the field for 14 days, no residues of either compound could be detected.

2. MC-A-600. Samples of Coastal bermudagrass, silage, and milk from animals fed treated silage from a study conducted at Tifton, Ga., in 1965 were reanalyzed by a sensitive and specific gas chromatographic procedure for MC-A-600 and its phenolic hydrolysis product. No trace (less than 0.01 ppm) of MC-A-600 or its hydrolysis product was found in the milk. Samples of grass treated with 2.0 pounds per acre taken the same day as application contained 38.7 and 1.20 ppm of MC-A-600 and its phenolic hydrolysis product, respectively. Silage 66 days old prepared from this grass contained 29.0 and 4.05 ppm of MC-A-600 and its phenol.

3. Imidan and Imidoxon. At Tifton, Ga., samples of soybeans, corn, and Coastal bermudagrass treated with Imidan at 0.25, 0.50, and 1.0 pound per acre were analyzed by gas chromatography. In all cases the Imidoxon residues were very low compared to those of Imidan. On Coastal bermudagrass the initial residues of Imidan averaged 12.3 ppm for the 0.25 pound per acre treatment, 27.0 ppm for the 0.50 pound treatment, and 52.0 ppm for the 1.00 pound treatment; the Imidoxon residues initially were 0.06, 0.13, and 0.36 ppm, respectively. Fifteen days after treatment the Imidan residues averaged 0.13, 0.36, and 0.57 ppm and no Imidoxon residues were detected. On corn the initial residues of Imidan were 2.67, 7.07, and 10.9 ppm, and those of Imidoxon 0.00, 0.01, and 0.02 ppm. Seven days after treatment the Imidan residues on corn were 0.09, 0.26, and 0.63 ppm and no Imidoxon was detected. On soybeans the initial residue of Imidan were 31.2, 55.4, and 82.2 ppm and those of Imidoxon were 0.03, 0.07, and 0.11 ppm. Fifteen days after treatment with Imidan residues were 0.10, 0.28, and 0.76 ppm and no Imidoxon was detected.

In another study at Tifton, cows were fed for 42 days on corn silage to which about 19 ppm of Imidan (dry basis) had been added. Analysis showed no detectable residues of Imidan or Imidoxon in the milk. No residues were

detected in samples of urine or feces taken 31 and 35 days after feeding was started. Blood cholinesterase activity of the animals appeared to be unaffected during the test period.

4. Dimethoate. At Beltsville, Md., corn was treated with dimethoate at rates of 32 and 8 oz per acre, harvested, chopped as silage, and samples taken for residue analyses. After one day samples from the 32-oz treatment contained an average residue of 7.0 ppm of dimethoate and about 0.2 ppm of the oxygen analog. In the 7-day samples the average dimethoate residue was 0.19 ppm and no oxygen analog was detected. The one-day samples from the 8-oz treatment contained an average residue of 1.27 ppm of dimethoate and less than 0.01 ppm of the oxygen analog. In the 7-day samples the average dimethoate residue was 0.53 ppm and less than 0.01 ppm of oxygen analog was present.

5. Bidrin and Azodrin. Milk from cows at Tifton, Ga., fed corn silage containing about 19 ppm of Bidrin (dry basis) for 28 days contained no detectable residues of these compounds. Urine taken during the same interval contained from 0.01 to 0.20 ppm of Bidrin and 0.134 to 0.268 ppm of Azodrin. Blood cholinesterase activity of the animals decreased as much as 50% during the test.

6. Dursban. Plots of corn and Coastal bermudagrass at Tifton, Ga., were treated with Dursban emulsifiable concentrate at 1.0 pound per acre. Samples were taken immediately after application and at intervals up to 21 days for the grass and 14 days for the corn. Samples of jar silage one month old prepared from the two treated crops also were analyzed. Analyses were made by gas chromatography. Immediately after application an average of 13.2 ppm of Dursban (on wet basis) and 0.12 ppm of the oxygen analog was found on the grass; 21 days later these levels had declined to 0.18 ppm and less than 0.004 ppm, respectively. On the corn the average initial deposits were 5.60 and 0.044 ppm, declining to 0.415 and 0.006 after 14 days. The levels of Dursban and its oxygen analog in the jar silage averaged 8.72 and 0.258 ppm, respectively, in the grass, and 3.10 and 0.037 ppm in the corn.

At Tifton, Ga., milk from cows fed Dursban at the rate of 0.65 mg/kg of body weight for 10 days contained trace amounts of Dursban (0.001 to 0.003 ppm). The oxygen analog of Dursban was not detected.

7. DDT. At Yakima, Wash., vegetation from upland meadows within the Burns tussock moth project was analyzed for DDT, which had been applied one year earlier by helicopter at the rate of 0.75 pound per acre. The average residues (ppm) of DDT isomers plus metabolites on a dry-weight basis for each type of vegetation were: sedge 2.07; lupine 0.41; sagebrush 1.22. Pretreatment samples of sedge contained 0.16 ppm and those of lupine and sagebrush each contained 1.4 ppm.

D. Biological Control

1. Grasshoppers. In 1966 natural enemies, mostly birds and dipterous larval parasites, were abundant and destroyed many grasshoppers in some areas of Arizona. At San Carlos in late September adults of Trachyrhachys mexicana were parasitized 25% by nemestrinid flies and at San Rafael Valley average parasitism of adult Morseiella flaviventris and Boopedon nubilum grasshoppers by nemestrinid larvae at five stations was 21.3% on September 7.

Four species of Protozoans and two viruses of grasshoppers are under study. Nosema locustae, a microsporidian, infects the fat bodies causing reduced fecundity and increased mortalities. N. acridophagus, another microsporidian, attacks various tissues of the host induces tumors and is highly virulent. Nosema n. sp. is a microsporidian, recently isolated, which infects the fat bodies of grasshoppers but is more virulent than N. locustae, probably because of a shorter life cycle. This organism is being studied in the laboratory. Malamoeba locustae, an amoebic protozoan, infects the midgut Malpighian tubule epithelia. This organism is not highly virulent to grasshoppers but does reduce vitality and fecundity. The two viruses appear very promising for use against grasshoppers. The inclusion body virus, which was isolated two years ago, infects the fat bodies and pathologically is quite similar to N. locustae. The non-inclusion body virus was isolated about one year ago and is still undergoing extensive laboratory investigations. This virus is highly virulent, infects the muscles of the host, causing 50% mortalities among nymphs in a period of five days.

Research is now underway under a cooperative agreement recently made with the University of Montana to study the lipid characterization of grasshopper fat bodies in relation to infection by the pathogen, M. locustae.

Under a grant to the University of Montana, a polyhedrosis virus (PV-1) and a non-inclusion virus (CV-1) isolated from grasshoppers are being studied. PV-1 affects the fat bodies and CV-1 the muscle tissue. These viruses have been partially purified by a sucrose density gradient ultracentrifugation technique and some of the physical and chemical properties determined.

2. Alfalfa Insects. A four year study at Lincoln, Nebr., on the parasitism of the alfalfa weevil in the area immediately east of the Rocky Mountains showed that the parasite, Bathyplectes curculionis, was easily detected wherever weevil larvae were collected. The highest rate of parasitism was 94%, but the rate of parasitism and magnitude of weevil populations fluctuated greatly. The relationships between these fluctuations are not clarified by the data but it is felt that the eastward spread of the weevil may be slowed by the parasite.

Bathyplectes anurus, a larval parasite of the alfalfa weevil, was released in Maryland for the first time in 1967. The incidence of B. curculionis and Tetrastichus incertus, the two widely distributed larval parasites in Maryland and New Jersey, was generally lower in 1967 than in 1966. The highest rate of parasitism by B. curculionis in survey fields was 15% in a New Jersey field and 3% in a Maryland field. Parasitism of larvae collected from fields on the Eastern Shore of Maryland was much higher - exceeding 40%. T. incertus occurred commonly in June when host populations were low, as usual. The adult parasite, Microctronus sp. "black" was recovered from a Beltsville field.

At Mesa, Ariz., nearly 1000 adults of Peridesmia discus, an egg parasite of the Egyptian alfalfa weevil, were released in February and nearly 2000 adults of Tetrastichus incertus, a larval parasite, were released in March 1967. From February to April B. curculionis, another larval parasite of this weevil, was found in several fields and parasitism ranged from 2 to 30%.

A research grant was recently awarded to the University of Kentucky to study the bionomics of Aphidius smithi, a parasite of the pea aphid, and to determine the effect of insecticides applied to alfalfa on this parasite.

3. Grass Insects. A parasitic Hymenoptera, identified as an apparently undescribed species of Tetrastichus has been found associated with bromegrass heads in Nebraska for a number of years. During the summer of 1966 it was determined by laboratory rearing that this Hymenoptera is a parasite of the bromegrass seed midge. The rate of parasitism was as high as 96% by mid-July.

At Weslaco, Tex., under a grant with the Texas Experiment Station, it was shown that air releases of grass infested with the Rhodesgrass scale parasite, Neodusmetia sangwani, at intervals of 1x1 or 1x2 miles was more effective than 2x2-mile intervals. The yield of grass (dry weight) in the biocontrol plots was 1851 pounds compared with 1021 pounds per acre in the check plot.

4. White-fringed Beetles. At Gulfport, Miss., 200,000 active DD-136 nematodes were applied to balled and burlapped and potted nursery plants infested with 20 field collected white-fringed beetle larvae each. Complete control was not achieved in any test.

In a survey to find naturally occurring diseases of the white-fringed beetle, over 2500 larvae have been received at Gulfport for examination. None were infected with parasitic nematodes. Several dead larvae were infected with a red bacterium.

Thuricide, Mattesia grandis, and nematode DD-136, tested as a dip and spray on peanut foliage treatments failed to control white-fringed beetle adults.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. White-fringed Beetles. In olfactometer tests at Gulfport, Miss., 35 materials were screened against white-fringed beetle larvae and 59 against the adults. None of them showed attractancy to the beetle.

A cooperative agreement was recently initiated at the University of Georgia to evaluate plant extracts and synthetic compounds as attractants for the white-fringed beetle.

2. Alfalfa Insects. The ovipositional responses of the alfalfa seed chalcid to chemicals occurring in alfalfa is being studied under a grant to the University of Wyoming. Of 81 chemicals tested 23 elicited a response when brought into contact with the ovipositor. Citric acid lineoleic acid, oleic acid, maltose and vitamin D_2 were among those chemicals causing a reaction.

At Blacksburg, Va., under a contract with Virginia Polytechnic Institute, an extract of alfalfa prepared with hot NaCl was more attractive to the alfalfa weevil than 14 other compounds. It was broken down into six fractions, two of which were quite active. In this same study apholate effectively sterilized the alfalfa weevil when both sexes were treated, but after 4-8 weeks the weevils began to regain their ability to reproduce.

F. Evaluation of Equipment for Insect Detection and Control

Research at Beltsville, Md., with liquid propane flamers to control the alfalfa weevil showed that flaming dormant alfalfa in March gave control essentially equal to that obtained with a standard insecticide application of methoxychlor-malathion. However, due to the abnormally early and extended period of larval damage, two treatments were necessary to protect the crop: either flaming plus an insecticide application prior to harvest, or two insecticide applications (one prior to harvest and one to the stubble following harvest).

G. Varietal Evaluation for Insect Resistance

1. Alfalfa Weevil. Definite progress was made at Beltsville, Md., in selection for an intensification of plant resistance to the alfalfa weevil. Most of the plant material was tested in several groups or populations of similar genetic make-up, such as winter hardiness and disease resistance. Seedling populations from intercrosses of selected clones are subjected to adult feeding until only 1-2% remain. These survivors are then subjected individually to larval survival, adult leaf feeding, and oviposition tests. Selections within each population is then intercrossed again for the next cycle of selection.

A total of 116 plants were selected from old-field stands of alfalfa in Maryland as a possible source of resistant germ plasm. A group of 12 clones showing extremes of susceptibility or resistance were selected for use as

checks in the laboratory screening program, in special laboratory studies, and in large-cage field studies.

At University, Park, Pa., an alfalfa nursery of 407 introductions was evaluated for alfalfa weevil damage in 1966. Differences in amount of feeding were present, but none of the plants was considered outstanding.

A research contract (jointly with Crops Research Division) was recently initiated with the Research Triangle Institute, Research Triangle Park, N. C., to study the relationship of alfalfa saponins to insect resistance.

2. Spotted Alfalfa Aphid and Pea Aphid. Tests at Lincoln, Nebr., with the pea aphid to determine its preference for detached leaves from susceptible and resistant alfalfa clones were conducted in environmental chambers at temperatures of 50° and 80° F. Analysis of variance showed that there was no interaction between the temperatures and the clones. However, the pea aphid at both temperatures preferred the more susceptible clones.

Experiments were conducted at Lincoln to determine the preference of the spotted alfalfa aphid on susceptible and resistant clones of alfalfa at 50° and 80° F. At 50° F there was generally less preference by the aphid for susceptible clones than at 80° F. The aphids exhibited a strong non-preference for certain resistant clones at both temperatures.

At Tucson, Ariz., 25 alfalfas and experimental lines, developed cooperatively by plant breeders and entomologists, were evaluated for resistance to the pea aphid and two biotypes of the spotted alfalfa aphid. Seedling survival ranged from 46 to 95% for entries tested against biotypes ENT-A and ENT-B of the spotted alfalfa aphid and 32 to 93% for entries tested against the pea aphid. Four experimental lines had 90% or better seedling survival against ENT-A whereas the check (Moapa) had only 46%. Five entries had 90% or better seedling survival against ENT-B whereas the check (Moapa) had 65%. Two entries had more than 90% seedling survival against the pea aphid.

At Reno, Nev., research under a cooperative agreement (jointly with Crops Research Division) showed that pea aphids exhibited a decided preference for an artificial diet to which steam distillates from a susceptible alfalfa variety were added. Pea aphids have been maintained as long as 32 days when fed through a membrane on an artificial diet.

At Tucson, Ariz., five alfalfas and experimentals were evaluated in greenhouse tests for resistance to the pea aphid and ENT-A and ENT-B of the spotted alfalfa aphid. An experimental, M-56-11 T.C., was rated as having the tallest plants and the highest percent of seedling survival against both species of aphids. Percent seedling survivals were 98, 96, and 68 against ENT-A, ENT-B, of the spotted alfalfa aphid, and the pea aphid, respectively, compared to 40, 50, and 40% survival for the check variety, Moapa.

At Tucson, Ariz., several hundred alfalfa plants were screened for resistance to the pea aphid and ENT-A of the spotted alfalfa aphid, and released to plant breeders. For Arizona breeders, 700 progenies from 59 two-clone combinations involving material from Mesa-Sirsa were screened for resistance to the pea aphid. For California, over 100 plants each from experimentals SW-28, SW-30, SW-31, and SW-42 were selected for resistance to both species of aphids. For Nevada, over 100 plants each from MSE and MSF were selected for resistance to both species of aphids.

At Mesa, Ariz., about 200 plants from different sources having root-rot tolerance were selected for resistance to ENT-A biotype of the spotted alfalfa aphid.

In a contract to Kansas State University to develop alfalfas with resistance to two or more insects, 32,670 seedling plants from intercrossing 73 spotted alfalfa aphid resistant plants and 84 pea aphid resistant plants were exposed to both aphids and 5,200 survived the test. Of 856 Cody x DuPuits plants cage tested, 365, 327, and 227 were resistant to the spotted alfalfa aphid, pea aphid, and both aphids, respectively.

3. Alfalfa Seed Chalcid. At Mesa, Ariz., progenies from a 22-clone synthetic were screened for resistance to field populations of the alfalfa seed chalcid. Among 90 plants screened from a total of 1400 progenies about half of them had a high level of resistance following greenhouse cage tests. Thus, the process of recycling and reselecting gave about 40-fold increase in the number of chalcid resistant plants.

4. Lygus Bugs. Several thousand plants representing progeny from Sirsa #9 were screened in field tests at Mesa. Thirteen plants were selected that were free from lygus damage. All material has been increased by propagation and prepared for antibiosis cage tests.

Research under a grant to Kansas State University showed that seed from alfalfa plants that survived severe lygus bug attack gave rise to plants more resistant than the population from which they were selected. Seed of 29 surviving plants sib pollinated within varieties produced plants that showed 17 lines were superior to their parents.

5. Leafhoppers. Twenty-two plants from Moapa alfalfa were selected for high tolerance to the leafhopper, Empoasca abrupta, from 3-year old plantings at Mesa, Ariz.

Five hundred and fifty plants in the 1966 potato leafhopper observation alfalfa nursery were evaluated at Lincoln, Nebr., and 68 clones having apparent leafhopper resistance were tested for resistance to both the pea aphid and spotted alfalfa aphid. Nineteen of the 68 plants were classified as having antibiosis resistance to both aphid species. These 19 plants were retained for use in the alfalfa breeding program to develop improved experimental synthetics with combined resistance to these three insect species.

6. Grasshoppers. Studies at Bozeman, Mont., on resistance of forage plants to grasshopper feeding showed that of eight plant species, green needlegrass, thickspike wheatgrass, and bluebunch wheatgrass were least preferred by adult migratory grasshoppers. The adults also gained the least weight and deposited the fewest egg pods when they were fed the least preferred plants.

7. Sweetclover Aphid. The great majority of evidence obtained at Lincoln, Nebr., from a study of the inheritance of resistance to the sweetclover aphid in yellow-flowered sweetclover indicated resistance was governed by a single gene pair with resistance dominant. However, the segregation resulting from certain individual crosses indicated that complimentary genes were present. Assuming complimentary genes, all data obtained that gave a satisfactory fit to a single gene hypothesis would be expected if one of the interacting gene pairs was homozygous dominant in both parents while the second allelic pair was segregating.

8. Sweetclover Weevil. Studies are underway at Lincoln, Nebr., to locate a source of resistance to the sweetclover weevil that would be as effective as Melilotus infesta, but which could be more readily crossed into the commercial types of sweetclover. Twenty-four recent Melilotus introductions were screened for weevil resistance during the 1966-67 greenhouse season. None of them were uniformly resistant, but individual plants appearing to have some degree of resistance were selected from some of them.

Under a grant to the University of Nebraska (jointly with Crops Research Division) a feeding stimulant and a deterrent have been found in sweetclover species resistant and susceptible to the sweetclover weevil. A second deterrent has been found in M. infesta which may account for the near immunity of this species to weevil feeding.

9. Grass Insects. At Tifton, Ga., a laboratory technique was developed to screen bermudagrass introductions and hybrids for resistance to newly hatched fall armyworm larvae. This technique detected differences between the grasses and also proved that first instar larvae eat only tender leaves and refuse sections from older leaves.

At Tifton 120 clones of Coastal bermudagrass were each infested with approximately 500 first instar larvae of the fall armyworm. Of the clones evaluated, 118 showed a high level of susceptibility to larval feeding. Two entries (Tifton Nos. 76 and 165) were less preferred for larval feeding indicating that hybridization and selection might be used to obtain genotypes having greater resistance.

At Tifton over 400 bermudagrasses were screened in the field for resistance to adult two-lined spittlebugs, and seven plant introductions (Tifton field numbers 36, 88, 390, 395, 401, 543, and 581) consistently received low damage ratings.

Over 1200 pearl millet inbreds were screened for resistance to fall armyworm larvae. Inbreds 153, 192, 266, 555, and 756 (Tifton numbers) have exhibited high resistance in repeated testing. There are indications that the biology of larvae is adversely affected when worms are forced to feed only on resistant plants. The weight gain of larvae fed only on a highly preferred inbred significantly exceeded that gained by larvae confined to a resistant inbred.

H. Insect Vectors of Diseases

Red Clover Virus. The clover root borer, Hylastinus obscurus, often associated with the occurrence of virus in the field, is being investigated at University Park, Pa., as a possible vector. Findings have been complicated by an unexplained development of virus in the test plants. A greenhouse sanitation program has been initiated in an effort to rectify the problem.

Research studies in Poland under P.L. 480 project E21-ENT-9 to study the vectors of virus diseases of legumes was completed in January 1967. Of greatest significance was the finding that the green peach aphid and the pea aphid could simultaneously transmit more than one legume virus.

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AREA NO. 6. SOYBEAN AND PEANUT INSECTS

Problem. Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. Basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resistant crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA AND COOPERATIVE PROGRAM

The Department has a limited program involving basic and applied research on insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists, and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations. Some oilseed crops are evaluated for resistance to insects at the Regional Plant Introduction Station at Ames, Iowa.

Additional research is conducted through two grants and two cooperative agreements with State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 2.5 scientist man-years. Of this number 0.5 man-year is devoted to basic biology; 0.3 to insecticidal control; and 0.1 to biological control; 1.4 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases; and 0.1 to program leadership.

In addition, Federal support of research in this area conducted under grants provides a total of 1.0 scientist man-year. Of this 0.2 man-year is devoted to research on basic biology; 0.2 to insecticidal control, 0.4 man-year to varietal resistance, and 0.2 man-year to insect vectors.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 9.0 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Soybean Insects. Studies at Columbia, Mo., on the comparative development of the corn earworm, Heliothis zea, on soybeans and corn showed that pupae from larvae developing on soybeans were significantly lighter (330 mg) than those developing on corn (473 mg). The rate of gain of the larvae was greater on corn than on soybeans.

In oviposition tests at Columbia, Mo., the corn earworm showed a preference for corn. Out of a total of 644 eggs, 575 were deposited on corn and only 69 were deposited on soybeans when both plants were available for oviposition. There was no indication of a biotype which either preferred soybeans for oviposition or developed on soybeans as well as on corn. It was shown, however, that the corn earworm can maintain itself on soybeans.

At Columbia in cage tests designed to determine the density of corn earworm larvae required to cause economic damage in soybeans, treatments consisting of 0, 3, 6, 12, and 24 second instar larvae per plant were replicated 8 times. Significant differences in earworm damage were not apparent until the density reached about 3 larvae per plant.

In cage tests at Columbia adult bean leaf beetles, at densities as high as 16 beetles per plant, caused only significant differences in yield of Harosoy soybeans.

In cage tests at Columbia infesting soybeans with 0, 5, or 10 broadheaded bugs, Alydus pilosulus, per plant, caused no reduction in the total number of seeds produced. However, the mean weight of beans produced was significantly greater in the uninfested cages. There was a highly significant decrease in the size of beans from the infested plants and the damaged beans averaged about 25% lighter. In cages with 5 bugs per plant 41.6% of the seeds were damaged and in cages with 10 bugs per plant 57.3% of the beans were damaged. In cages with no bugs only 2.8% of the seeds were damaged. Subsequent examination of the damaged beans bacteriologically showed the presence of the yeast spot disease organism.

A cooperative agreement was recently initiated at Mississippi State University to study the biology and control of soybean insects particularly the pod and foliage feeders and determine the residues resulting from insecticide applications.

2. Peanut Insects. At Tifton, Ga., artificially infesting field-grown peanut plants with lesser cornstalk borer eggs showed that the larvae

damage the plants at ground level, pods, and pegs, and that the amount of damage was associated with infestation level. This study provided information for separating lesser cornstalk borer larval feeding damage from that of a complex of other insects infesting peanuts.

Investigations at Tifton showed that development of lesser cornstalk borer eggs did not occur at 0.5° C and 10.0° C. At 18° C hatch was complete in approximately 428 hours. At 33° C hatch was complete in 52 hours. At 36.5° C approximately 34% of eggs hatched in less than 48 hours, but approximately 8% hatched as late as 72 hours and approximately 34% failed to hatch.

3. Sunflower Insects. A grant was recently negotiated with the Texas Experiment Station to study the biology and control of the sunflower moth, a very serious pest of this oilseed crop.

B. Insecticidal and Cultural Control

1. Soybean Insects. At Columbia, Mo., soybeans treated with DDT+parathion yielded 38.4 bushels compared to 22.1 bushels in the untreated check. Plots treated with carbaryl yielded only 12.3 bushels per acre due to phytotoxicity and severe spider mite damage. The DDT+parathion plots continued to yield better than the check in later maturing varieties but differences were not marked. The DDT+parathion treated plots in varieties of two maturity dates had significantly higher seed quality than the untreated beans.

At Columbia carbaryl at two pounds per acre and methyl-parathion at one pound and a mixture containing one pound DDT plus two pounds toxaphene were applied by air to control corn earworm larvae on soybeans. After 24 hours methyl-parathion showed a 50.8% reduction in earworms, and after three days, 76.3%. DDT+toxaphene mixture and carbaryl controlled only 27.3% and 41.7% of the larvae at 24 hours, but five days later control by these materials was 85.4% and 89.1%, respectively.

Excellent control of thrips was obtained at Columbia using several insecticides including carbaryl, Azodrin, TDE, DDT+parathion, and others. The yield of soybeans was not significantly greater in treated plots.

C. Insecticide Residue Determinations

1. Peanuts. At Beltsville, Md., 25 samples of peanut butter from processing plants in different areas were analyzed for dieldrin residues. No dieldrin residues were found in any of the samples.

D. Evaluation of Equipment for Insect Detection and Control

1. Soybean Insects. At Columbia, Mo., an experimental ultra low volume ground applicator was tested. This applicator consisted of three spinning-cone distributors with three 6" fans mounted behind. The insecticide was metered to the cone distributor by a metering pump and the apparatus was powered by a gasoline driven alternator. The machine was mounted on a two-wheeled bicycle cart. Tests against the green stink bug and the corn earworm indicated that this method of application may be useful in the control of soybean insects.

E. Varietal Evaluation for Insect Resistance

1. Soybean Insects. At Columbia evaluation of soybeans for resistance to green stink bug damage showed that there was a significant difference between many of the varieties. Although differences were observed, the lines showing the least damage did not differe significantly from the variety Harasoy-63.

2. Peanut Insects.

At Tifton, Ga., host plant resistance investigations in 1965 and 1966 with 14 advanced peanut lines showed that differential damage by some insects occurred among plant types and varieties. Thrips damage to Runner and Virginia type plants in 1966 was significantly higher than among Spanish type plants. The same relationship was also recorded in 1965. Foliage feeding damage by the corn earworm in both seasons was significantly higher among Spanish than among Runner and Virginia type plants. Non-preference to larval leaf ragging was indicated for the varieties Runner Check, Virginia Bunch 67, Florigiant, Fla. Exp. 416, and Ga. 119-20. Varieties Starr, Argentine, Spanish Check, and NC-2 indicated some resistance to thrips.

At Tifton 54 wild peanut varieties, maintained as germ plasm sources for genetic studies, were subjected to mites, Tetranychus tumidellus, in the greenhouse. Through a 5-month period, a high level of tolerance to mite infestation was exhibited by 52 of the varieties.

Two varieties (Tifton entries A83 and A132) were killed by mites while five varieties (Tifton entries A22, A78, A79, A147, and A148) exhibited a high level of resistance.

At Tifton an initial test was carried out in the greenhouse with peanut seedlings to determine the feasibility of using the flat-planted seedling survival technique for rapid mass varietal resistance screening. Of 106 peanut lines artificially infested with lesser cornstalk borer eggs, approximately 15 entries showed a high level of seedling survival.

In 1967 resistance to thrips was investigated in the field among 343 peanut lines and two indicated a high level of resistance.

Under a research grant with Oklahoma State University, significant differences in thrips damage were observed among 481 peanut lines tested in the field. Sixty-one entries were selected as possible resistants. It was found that rating thrips damage on the last unfurled leaf on 20 plants per plot gave results comparable to those obtained by rating all damaged leaves on 20 plants.

3. Other Oilseed Crops. Species of a flea beetle, Phyllotreta sp., caused injury to plant introductions of the oilseed crops Crambe spp. and Brassica spp. at Ames, Iowa. The injury was typical of flea beetle feeding and consisted of small holes eaten in the leaves. Brassica campestris and B. napus were heavily fed on and one accession of B. napus had an average of 26.0 feeding scars per leaf. B. hirta showed the least injury of any of the Brassica spp. and one accession, PI 312849, had 0 feeding scars in a random count of 100 leaves.

Crambe abyssinica and C. hispanica showed considerably less flea beetle injury than did either B. campestris or B. napus. There appears to be sufficient resistance in C. abyssinica to this flea beetle that it should not become a serious problem if crambe becomes a major crop. However, it is of importance to note that several accessions of crambe do not possess this resistance, especially PI 281732. If agronomically desirable characteristics from such accessions are incorporated into improved varieties of crambe without regard to flea beetle resistance, susceptibility to the insect could be transferred also.

F. Insect Vectors of Diseases

1. Peanuts. Research under a grant to the University of North Carolina showed that peanut plants infected with peanut stunt were often in fields adjacent to pastures where clover was infected with stunt virus. This suggests that viruliferous insects spread the disease. The lowest incidence of peanut stunt was found in plots treated with phorate at planting and diazinon at pegging time. Plots treated early with malathion contained more infected plants than untreated plots possibly because the partial insect control obtained kept the plants more attractive for some insects.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

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AREA NO. 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem. Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of $900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in many counties in Michigan, Indiana, Illinois, Pennsylvania, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk, and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to maize dwarf mosaic and corn stunt recently found in several North Central and Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly at Lafayette, Ind., and Manhattan, Kans.; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and

mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Fargo, N. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall army-worm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Wooster, Ohio, State College, Miss., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Research on insects attacking the major cereal grains in Africa is being conducted under U.S. AID Contract in Zaria, Nigeria, and Serere, Uganda. Additional research is being conducted under ARS contracts and grants on the biology and control of the cereal leaf beetle with Michigan, Indiana, and Ohio Experiment Stations, and vectors of corn stunt virus with Mississippi State University, nature of resistance of corn to the European corn borer with Iowa State University. Nature of resistance of small grains to greenbug with Oklahoma State University, and nature of resistance of corn to corn earworm with Missouri University and insect communication in the infrared region with Michigan University, Ann Arbor, Mich.; University of California at Berkley, and Georgia Tech at Atlanta, Ga.; transmission of viruses causing stunting of corn, with Missouri University and Ohio University, and ecological factors affecting efficiency of Trichogramma spp. with Louisiana State University.

The Federal scientific effort devoted to research in this area totals 43.3 scientist man-years. Of this number 10.8 is devoted to basic biology, physiology, and nutrition; 3.5 to insecticidal and cultural control; 1.8 to insecticide residue determinations; 4.1 to biological control; 2.9 to insect sterility, attractants, and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 15.7 to varietal evaluation for insect resistance; 2.8 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-87 "Studies of the biotypes of the European corn borer." A P.L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize with Special Reference to Stalk Borers." Projects A7-ENT-31 in India, Investigations on insect pests of sorghum and millets," E21-ENT-14, in Poland, "Studies Regarding the Bionomics, Economic Importance and Natural Control Factors Affecting Oulema Species (Cereal Leaf Beetle) in Poland," and E30-ENT-3 in Yugoslavia on "Parasites, Predators, and Pathogenic Organisms

Study of the Cereal Leaf Beetle and Resistance of Domestic and Foreign Small Grain Varieties to the Insect, are also being conducted.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 37.7 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Corn Insects. Ecological data on the European corn borer at Ankeny, Iowa, showed the following populations per acre: early spring 3,042, late spring 975, midsummer 1,854, and postharvest 6,271.

Field experiments investigating the possible existence of biotypes of the European corn borer were continued at Ankeny, Iowa. Borer populations from seven geographic areas, on three host types were studied. Results showed that the Minnesota and Missouri borers differ distinctly and Iowa was intermediate in several ecological characteristics. It was also shown that the biology of each biotype is influenced by the ecological conditions such as location of the experimental plot and host variety. Comparing the diapause of the seven populations, the percent diapause for first generation borers seemed to increase with the northern latitude of the origin of the population.

Laboratory data at Ankeny has shown that corn pollen is important in the nutrition of young European corn borer larvae. Field data showed that pollen was important for good establishment of second-brood larvae on susceptible inbreds, but had no effect on the establishment of the larvae on resistant inbreds.

Satisfactory methods have been developed at Ankeny for rearing European corn borer on artificial media. However, conflicting field data on the level of establishment of their offspring on inbred lines of corn compared with those of field-collected moths have been obtained. In 1966 establishment on susceptible inbred WF9 by larvae from parental stock reared continuously (30+ generations) on the artificial diet was at a low level compared with larval establishment from a field-collected population. It is not unreasonable to assume that larvae reared on an artificial diet for many generations may become so acclimated to the diet that they no longer prefer corn as host plant.

At Wooster, Ohio, mass selection of a strain of nondiapause corn borer for seven generations has increased the incidence of nondiapause in an Ohio population from 16 to 88%.

Gossypol mixed in the diet was significantly toxic, reduced larval and pupal weight, and increased the time to pupation at the lowest rate tested

(0.10%). This percentage is much lower than that found in many commercial glanded cotton foliage.

The southwestern corn borer continues to spread and was found in one additional county in Mississippi, two in Alabama, four in Tennessee, and eight in Kentucky in 1966. This was the first record of the borer in Kentucky.

A satisfactory laboratory technique for rearing the southwestern corn borer has been developed at State College, Miss.

In Mississippi second generation southwestern corn borer females were dissected to determine the percent mated. Mating was determined by the presence of one or more spermatophores. Of those mated 70% had one spermatophore, 19% had two, 10% had three, and 1% had four. This indicates that this insect will often mate more than once.

At Tifton, Ga., work has been progressing in plotting the various sensors on the antennae and the legs of the corn earworm moth. In a detailed study of the morphology of the antenna, 14 separate and distinct types of sensors have been located. These sensors have been plotted both with respect to the numbers present and to their physical configuration on the antennae. Electrophysiological work has shown that one sensor, the scape and pedicel dome sensor, of the noctuid and saturnid antennae responds to visible radiation.

At Tifton, Ga., data for the oxygen consumption of the larval and pupal stages of the corn earworm were obtained. On the basis of microliters per milligram per hour the pupae exhibit a typical U-shaped curve, while larval curve is inversely related to total weight.

Winter mortality of the rice weevil was studied at four locations in Mississippi. Mortality of the immature stages inside the corn kernels showed a definite increase progressing northward, Poplarville, the southernmost location, averaged 18.2% mortality, Newton 34.2%, State College 48.2%, and Holly Springs 56.3%. These results seem to be correlated with lower temperatures and moisture content of the grain at the northern locations.

At Tifton, Ga., the mass production of fall armyworm and corn earworm to be used in research has continued. The casein-wheat germ diet, regularly used for rearing corn earworm, has been replaced with a less expensive pinto bean diet. The bean diet has been satisfactorily modified to shorten length of time required for pupation and to obtain a more uniform rate of pupation.

A survey to determine population levels of the corn earworm, fall armyworm, and sugarcane borer is underway on St. Croix, U. S. Virgin Islands. Results show that all three species are firmly established on St. Croix.

Definite population peaks of the fall armyworm and corn earworm occurred in early May and early to mid-June. Infestations of the sugarcane borer are confined to the central portion of the Island where sugarcane fields exist. Additional data pertaining to alternate host plants and levels of parasitism are being collected.

Studies initiated at Tifton, Ga., were conducted to determine if the fall armyworm overwinters in the Southern States. None were collected in traps placed along roadsides between Tifton, Ga., and Baton Rouge, La., during the last week of March, but moths were collected at Houma, La., during the first week of May. In Mississippi fall armyworm males first appeared May 4 in Poplarville, June 1 in Newton, May 12 in State College, and May 25 in Holly Springs. Fall armyworm males were collected on April 24 in Tifton, Ga. These data indicate that the fall armyworm may have survived the mild winter of 1967 and overwintered along the Gulf Coast.

The northern and western corn rootworms have been reported as being host specific for corn. However, laboratory and field tests at Brookings, S. Dak., have shown conclusively that these insects can complete their life cycle and produce fertile adults when reared on certain varieties of wheat and barley and a number of the grasses common to the Midwest.

Simple maze devices have shown that the larvae of the western corn rootworm are attracted to the roots of their primary host, corn, and to a nonhost, cultivated oats. The reason that oats is a nonhost is therefore apparently not due to the presence of a repellant nor to the lack of an attractant. Larvae of the western corn rootworm maxillectomized with a small laser beam and placed on oat roots lived longer than normal larvae. This may indicate that oats lacks a feeding stimulant usually sensed by a normal larva.

2. Small Grain and Sorghum Insects. Survival and reproduction of four species of aphids under three types of filters were studied at Brookings, S. Dak. Colored cellophane filters had negligible influence on aphid performance, probably because they transmitted across the visable range and differed little in their spectral transmission. Colored Wratten filters, however, had a pronounced effect on aphid performance. The English grain aphid, greenbug, and corn leaf aphid survived longer and reproduced more under a yellow Wratten filter. The apple grain aphid survived longer under a green filter. In general, cereal aphids performed best under the same color they chose in preference tests. Color preferences of adults and nymphs of the four aphid species were tested under controlled conditions in the laboratory. Adults and nymphs of apple grain aphid and nymphs of corn leaf aphid preferred green over yellow, red, or blue. Adults of corn leaf aphid, and adults and nymphs of English grain aphid and greenbugs preferred yellow over other colors available.

In studies at Brookings, S. Dak., false wireworm adults, Embaphion muricatum, were given choices of seeds of several common crops and grasses.

Seeds showing the highest rate of feeding included alfalfa, hulless oats, rye, sand lovegrass, sweetclover, and wheat. Corn, forage sorghum, grain sorghum, green foxtail, hulless barley were moderaly preferred. Many seeds showed little or no feeding by the beetles even when other foods were denied them. These included barley, big bluestem, bluegrass, bromegrass, crested wheatgrass, flax, green needlegrass, Indiangrass, little bluestem, oats, Russian wild rye, sand bluestem, side-oats grama, soybean, sudan grass, sugar beet, switch grass, western wheatgrass, and yellow foxtail.

A species of flase wireworm, Eleodes obsoleta, was reared on ground wheat in the absence of soil in the laboratory. It was found to have nine larval instars. The length of the larval period averaged 133 days, the prepupal period 6.8 days and the pupal period 19.9 days or an average life cycle of 159.7 days. If the life cycle were the same length in the field, this species would have only one generation per year in South Dakota. As a part of the studies to clarify the biology and ecology of false wireworms, pitfall traps were set in wheat fields throughout South Dakota in three general types of soil to determine the distribution of various false wireworm species. The preference of nine species of false wireworms was correlated with three basic soil types. All species except one were much more plentiful in the semi-arid portions of the state.

A census of wheat stem sawfly populations in 20 counties of western North Dakota was conducted in the fall of 1966. Percent fields infested per county ranged from 100 to 12%. Greatest damage from sawfly stem cutting occurred in the northwestern counties. Greatest damage from sawfly stem tunneling occurred in the southwestern counties. This census assisted Experiment Station workers in equitably distributing seed of the newly released sawfly resistant variety, Fortuna, to growers in the western half of North Dakota.

At Lafayette, Ind., studies of the racial composition of field populations substantiate the apparent buildup of Race B populations of Hessian fly in Indiana where resistant varieties having the resistant H_3 gene have been grown since 1955. Race B was the predominant race in nine populations collected from areas of previously infested W38 resistant fields. Although much less prevalent, but possibly more important, was the high frequency of Race D individuals. This race can infest both the wheats having H_3 and H_6 genes for resistance, making it desirable that varieties having the H_5 gene be released in the near future. Race A was still the predominant race in three populations collected from previously infested non-resistant fields although Race B was present in large numbers.

Progeny tests of a population from the hard wheat region in western Kansas showed the Great Plains race to be predominant with Race A occurring only at a low frequency. However, in a population from northeastern Kansas near the eastern edge of the soft wheat region, Race A was the predominant race. The Great Plains race occurred at a fairly high frequency and Races B and C occurred at a low frequency.

Genetic studies of the Hessian fly have shown that the inability of the Great Plains race of Hessian fly to infest wheats grown in the eastern soft wheat region is dominant to the ability of Races A, B, C, and D to infest these same wheats. First generation progenies, from reciprocal mating between individuals of the Great Plains race and Races A, B, C, and D, die on wheats grown in the eastern soft wheat region, including such historically susceptible varieties as Trumbull and Vigo.

Other studies involving reciprocal matings between individuals from Races A and B have shown that the inability of Race A to infest wheats having the H_3 gene for resistance is dominant to the ability of Race B to infest these same wheats.

Inheritance studies involving the Great Plains race and Race A and Races A and B have definitely shown that there is chromosomal elimination of paternally derived chromosomes during spermatogenesis resulting in only one functional sperm, having only maternally derived chromosomes.

Studies at Stillwater, Okla., on flight habits of aphids showed that they fly in every month, but heaviest flights were recorded during September, October, November, and December and in the spring months of March, April, and May.

Observations on sexual behavior of the cereal leaf beetle at East Lansing, Mich., indicated an absence of courtship prior to mating but some manifestations on the part of the male have been observed after mating. Time of actual copulation ranges from 4 to 121 minutes, with a time lapse between the end of copulation and separation of the male and female. Laboratory studies revealed a marked effect on oviposition behavior when adult cereal leaf beetles are exposed to 16 hours of light as contrasted to 8 or 24 hours. Oviposition is obtained after as little as four weeks of cold storage when beetles are kept in a 16-hour photoperiod whereas as much as 16 weeks of storage is needed before oviposition occurs under the other photoperiodic conditions. Under laboratory conditions some virgin female cereal leaf beetles were capable of ovarian development and oviposition when exposed to a 16-hour photoperiod following a minimum of 12 weeks of cold storage. Eighty percent of the virgin females developed ovaries and an average of four eggs per female were deposited when the insects were confined under lantern globe cages over potted barley. No embryonic development occurred in the eggs obtained from these females.

Laboratory studies indicated the possibility that only the female cereal leaf beetle has an obligatory diapause. Mating and oviposition does not normally occur until after the female has been in diapause and is subsequently exposed to proper photoperiodic conditions. However, when pre-diapause males are placed with virgin post-diapause females under suitable conditions, mating and oviposition occur in the same manner as when post-diapause males are used.

Attempts have been made to isolate a non-diapausing strain of cereal leaf beetle. However, no detectable strain has been found to date.

Diapause in the adult cereal leaf beetle was effectively terminated by topical treatment with the synthetic juvenile gonadatropic hormone, trans, trans, 10, 11, epoxyfarnesenic acid methyl ester. Subsequent work has indicated that only the females need be treated.

Studies in Zaria, Nigeria, showed three major pests of sorghums. These are the shoot fly, stem borers, and the sorghum midge. Information has been obtained on the biology of these insects.

B. Insecticidal and Cultural Control

1. Corn Insects. At Ankeny, Iowa, eight systemic insecticides were evaluated for European corn borer control. American Cyanamid CL-47470 (4 pounds per acre), Niagara NIA-10242 (2 and 4 pounds per acre), ENT-27396 (2 pounds per acre, Bay 39007 (2 pounds per acre), and ENT-27389 (1.5 pounds per acre) gave encouraging results. More than 25 insecticides were tested against first-generation borers at various rates and mixtures. Phorate, CL-47470, diazinon, Dursban, Niagara NIA-10242, Stauffer N-2790, EPN, ENT-25 15-d, and ENT-27396 were as effective as DDT. Twenty-two insecticides were evaluated for control of second-generation borers. Dursban, diazinon, EPN, ENT-27320, ENT-27392, and a mixture of parathion and endrin were outstanding at the rates tested.

Three experiments were conducted to examine any effects that row widths of 20, 30, and 40 inches and plant populations of 13, 17, and 26 thousand plants per acre might have on the establishment of artificial infestations of the borer and control on field corn with granular insecticides. No differences were indicated in establishment of first-generation borers. Granules applied on the basis of foot of row per acre resulted in no significant differences due to row width, plant population, or the interaction of these for first- and second-generation borers.

Two experiments on 20 inbred and 30 single cross corns to examine the effect of visible phytotoxicity resulting from the application of diazinon on total yield, seed weight, and test weight were conducted. Differences of foliar response between entries were evident but this was not reflected by yields.

In Mississippi, Niagara NIA-10242 granules (5%) at 1.0 pound per acre per application as a soil systemic insecticide did not significantly reduce southwestern corn borer damage in dent corn in tests at two locations. Foliar treatments of endrin, endosulfan, and NIA-10242 at 0.5 pound per acre per application significantly reduced southwestern corn borer damage when two applications per generation were applied for the second and third generations. Two applications of Azodrin per generation at 1.0 pound per acre per application, applied as a spray in the whorls of the plants, showed potential in controlling the borer.

Several experimental compounds were effective in controlling fall armyworms in laboratory experiments in Tifton, Ga. ENT-27449, 27386-a, 27448, 27409, and 27408 gave 100% mortality of third instar fall armyworm larvae in 24 hours.

In laboratory tests at Tifton fall armyworms were fed leaf discs treated with varying quantities of Azodrin and pp'-DDT. Azodrin was as effective as DDT in controlling third instar larvae. Control of the corn earworm and fall armyworm in field plots of sweet corn was significantly better with one pound per acre Azodrin than with two pounds per acre DDT.

At Brookings, S. Dak., aldrin resistant corn rootworm beetles absorbed topically applied aldrin and dieldrin more rapidly than the susceptible insects. However, the concentration of insecticides in the resistant insect remained relatively constant after absorption at about 50% of the applied 1 µg per insect dose as a result of excretion of both aldrin and dieldrin. Relatively low amounts of aldrin and dieldrin were excreted by the susceptible insect. Susceptible insects converted no dieldrin to aldrin whereas the resistant populations converted a sizeable quantity of dieldrin to aldrin. Both aldrin susceptible and resistant strains converted aldrin to dieldrin at about the same rate. Aldrin and dieldrin appear to be the only metabolites found in the treated insects.

2. Small Grain Insects. In tests at Bozeman, Mont., no insecticides have been found more effective against wheat stem sawfly than heptachlor in furrow applications. The additive, dimethyl sulfoxide (DMSO), used with oxydemetonmethyl in a foliage application gave control equal to that of heptachlor in a furrow application.

In integrated control tests for cereal aphids at Brookings, S. Dak., the LD_{50} values of malathion for the insect predators of cereal aphids and the English grain aphid in South Dakota such as lady beetles, nabids, and lacewing flies, indicated that all insect predators tested were less vulnerable to the insecticide than the aphid. Predators escaped significant mortality after feeding on malathion-poisoned aphids treated topically at the same dosage levels as in the contact toxicity studies with predators. The potential for integrated control of cereal aphids with selected dosages of malathion appears promising. Similar tests with parathion, in the preliminary stage, have indicated that parathion is 20 to 30 times more toxic to adults of lady beetles and lacewing flies than malathion. The toxicity differential for the English grain aphid does not appear to be as great.

At Stillwater, Okla., further insecticide phytotoxicity study tests demonstrated the differential reaction among sorghums to insecticides. Grain sorghum variety OK 612 was severely burned by sprays of Bidrin and methyl parathion, but there was no damage to variety RS 610. There was no damage to either variety when sprayed with diazinon. In studies conducted to determine the cause of phytotoxicity to susceptible sorghums when sprayed with Bidrin, first injury appeared around stomata. Then there was shrinkage

and disintegration of the chloroplasts. Breakdown of the chloroplasts and the cells caused the tracheary elements to become filled with polysaccharide material. After 48 hours following spray application the entire leaf was dead.

At Zaria, Nigeria, carbaryl gave satisfactory control of sorghum stem borers.

Technical liquid disulfoton applied as a seed treatment on Rogers barley and Cimarron oats at rates of 16, 8, 6, 4, and 2 oz per 100 pounds seed resulted in 100% control of greenbugs at all rates up to 24 hours, but after 144 hours with reinfestation, there was little residual toxicity. On Ponca wheat control was 82% with the 16-oz rate of application, but it was ineffective at lower rates. On the basis of these tests it is not believed that liquid disulfoton would be effective as a seed treatment for wheat without use of stickers, but it would be effective for barley and oats for a short period. Greenbugs were effectively controlled by spray applications of Azodrin, disultoton, GC-6506, and Dursban. Fourteen days after treatment all materials at all rates were still giving 90% control. Experimental compound ENT-27398 gave less than 50% control at the .5-pound per acre rate. The effective chemicals resulted in a 5-1/2 bushel per acre increase in wheat yields over yields of unsprayed checks.

A heavy chinch bug infestation developed early in the spring of 1967 in a field of Will barley seeded in a sorghum stubble field. Parathion, Bay 39007, dimethoate, disulfoton, toxaphene, and diazinon were applied at the rate of .4 pound per acre and carbaryl WP at 1-1/2 pounds actual toxicant per acre. Best control was obtained with parathion and carbaryl WP. Yields were increased 18.7 bushels and 10.3 bushels per acre over unsprayed checks.

At East Lansing, Mich., spray programs designed to suppress adult cereal leaf beetle populations were evaluated from an integrated control approach. Blanket spray programs using an ultra low volume application of malathion at 4 oz per acre were superior to selective field spraying of the same dosage for adult beetle control. However, time of application is a critical factor.

In research conduted under cooperative agreement at East Lansing, excellent protection of spring seeded oats was obtained under condition of high cereal leaf beetle populations through the use of a seed treatment of Bay 39007 at 1, 2, 4, and 8 ounces per 100 pounds of grain. Seed treatment with Niagara NIA-10242 and Union Carbide UC-21149 have also given good control.

C. Insecticide Residue Determinations

1. Corn Insects. Chemists at Tifton, Ga., developed gas chromatographic methods for analyzing Azodrin and Bidrin. The methods employ the melpar

flame photometric detector with the 526 mμ interference filter. Samples are blended with chloroform and the raw extracts are analyzed with no further cleanup necessary. Recoveries from sweet corn spiked with Azodrin (0.05-5.00 ppm) prior to extraction were better than 95%.

Residues of DDT-malathion, applied at 0.4 and 1.6 pounds per acre, respectively, were determined on plants after each of five application dates and at harvest time. After each of the five applications, residues ranged from 4 to 25 ppm. Residues on plants averaged 6.25 ppm DDT and 0.82 ppm malathion at harvest time.

A spectrophotofluoremetric (SPF) method was developed at the Tifton laboratory (in cooperation with Beltsville, Md., and Ankeny, Iowa, laboratories) for the analysis of 6-methoxybenzo-xazolinone (6-MBOA) in corn. This method has now been used to provide supplementary information on various lines of corn previously evaluated by several biological and chemical techniques.

D. Biological Control

1. Corn Insects. Studies at Ankeny, Iowa, showed that the nematode DD-136 was not effective in controlling the corn borer in the field, although it did kill larvae, pupae, and adults in the laboratory. Applications of 25,000, 50,000 and 100,000 nematodes per square foot of oat-seeded corn stalk debris failed to give control of the overwintering corn borer larvae. It appears that field conditions were such that the nematodes were not able to reach the borers in the corn stalks.

Bacillus thuringiensis applications in Iowa gave good results in the laboratory but were not as successful in controlling the borer in the field as in previous years. One explanation of this could be the lower viable spore counts and the difference in formulation of the products compared with past preparations.

Perezia pyraustae infection in European corn borer has been low in the Boone County, Iowa, study area for the past year but a slight increase was observed in the spring of 1967. In March 9% of the borers were infected and in April 18% were infected.

Preliminary laboratory tests using a new formulation of Thuricide against the southwestern corn borer in Mississippi have shown some control potential.

At Lafayette, Ind., quantitative studies with the fall armyworm nuclear polyhedrosis virus indicate an LD_{45} for fourth instar fall armyworm of 2.66×10^8 polyhedral inclusion bodies. These values are much higher than the LD_{50} values reported for fourth instar cabbage loopers treated in the same manner with cabbage looper nuclear polyhedrosis virus. Efforts are underway to determine why the fall armyworm virus is less effective and to increase its effectiveness.

Stored corn from Poplarville, Miss., and Baton Rouge, La., was examined for possible parasites of the rice weevil. Three species have been collected and were identified as Anisopteromalus calandrae, Habrocytus cereallae, and Zeteticontus sp.

Non-inclusion virus-like particles (150 X 500 mμ) were detected in fat bodies of four species of adult Carabid beetles which are predators of corn rootworms. Disease insects exhibit a distended abdomen. The hemolymph has a chalky-white appearance which could be caused by "free virus" particles. In ultrastructural studies, only the cytoplasm of the fat body is infected. Cell nuclei do not appear to be invaded. Each particle consists of a dense homogenous core bounded by a double membrane.

2. Small Grain and Sorghum Insects. Collyria calcitrator, a parasite of the wheat stem sawfly was released in infested fields in Montana. Some parasites were caged on wheat with the sawfly, wheat plants collected in the fall and inhabiting insects reared from them. One male C. calcitrator was obtained in this test, but none have been recovered from field releases.

A native parasite, Bracon cephi, is an important factor in controlling the wheat stem sawfly in portions of North Dakota. Evidence supporting the conclusion that this parasite is effective throughout the larval developmental period of the sawfly was obtained. Resistance or susceptibility of wheat varieties to the sawfly influenced both sawfly and parasite numbers. The parasite is more efficient at lower sawfly densities in resistant varieties than at higher sawfly densities in susceptible varieties.

A survey of the parasites of the wheat stem maggot fly, Meromyza americana, infesting wheat, rye, barley, and quackgrass in South Dakota showed the following parasites to be present: B. meromyzae, Coelinidea meromyzae, C. ferruginea, Bubeckia fallax, Eupelmus allynii, and Amblymerus spp. Parasitism ranged 17 and 28% in wheat down to 3% in barley. Emergence of parasites varied significantly with geographic area.

Approximately 75,000 egg parasites, Anaphes flavipes, of the cereal leaf beetle have been released at three locations in Michigan. Percent parasitization has not yet been determined but parasitized eggs have been found 40 feet from one release point and 60 feet from another.

Studies at Stillwater, Okla., indicated that spiders may be of considerable economic importance in controlling insects infesting sorghums. Several spider species which were considered as being the most important in this respect were used in laboratory feeding and mass-rearing studies. They feed readily on a large number of larval and adult insect forms, and techniques have been developed for obtaining viable eggs. Spiders were taken from a Johnson-Taylor suction trap mounted on a 40-foot-high building during every month of the year. The collection of the "ballooning" spiders throughout the year is further evidence of their possible importance

as biological control factors. Also, they are present in fields from the time plants emerge from the soil until the crops mature. Their populations increase as the size of the plants increases and as insect populations increase.

Research conducted under a P.L. 480 project has shown that there are several parasites of the cereal leaf beetle in Poland. Cultures of one parasite, Tetrastichus julis, is available to send to the United States.

In research conducted under a P.L. 480 project in Yugoslavia, an egg predator, Nabus feriodes, was found that destroys more than 50% of the cereal leaf beetle during the early part of the season. The egg parasite, Anaphes flavipes, destroys eggs during the later part of the oviposition period. A shipment of this species has been received in the United States and releases have been made.

In studies conducted at Purdue University on cereal leaf beetle parasites under a cooperative agreement, laboratory cultures of three larval parasites, Lemophagus, Tersilochus, and Tetrastichus, have been established and rearing procedures have been developed for the cereal leaf beetle egg parasite, A. flavipes.

In studies conducted under a research grant at Columbus, Ohio, no diseases have been found of the cereal leaf beetle which show promise for control. A fungus, Beauveria bassiana, was found in laboratory cultures. Unidentified intra-cellular bodies have been found within the adipose tissue which may be due to degeneration of normal cellular constitutents resulting from inadequate nutrition.

E. Insect Sterility, Attractants, and Other New Approaches

1. Corn Insects. At Ankeny, Iowa, seven-day-old European corn borers were fed media containing tepa and adult males which developed from these larvae were sterile, but mating of the tepa treated ones was reduced.

In studies at Ankeny, Iowa, on the biochemical nature of natural resistance of corn to the European corn borer, it has been shown that the compound 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one is an effective feeding deterrent for larvae of the European corn borer. The conclusion seems clear that this compound is a major factor in the natural resistance of corn to the European corn borer. Chemically related compounds, 2,4-dihydroxy-1,4-benzoxazin-3-one, 2-hydroxy-1,4-benzoxazin-3-one, 2-hydroxy-7-methoxy-1,4-benzoxazin-3-one, and 2-O-glucosyl-7-methoxy-1,4-benzoxazin-3-one have also been found in corn tissue. These compounds are present in seedling plants throughout the development of the plant. Bioassay tests with the European corn borer have shown that N-OH benzoxazinones exert an antibiotic effect upon the borer, while N-H benzoxazin-3-ones have no apparent physiological effect on the insect.

A sex pheromone of the European corn borer has been isolated from the female adult. The pheromone functions as a sex stimulant to the male insect. The pheromone appears to play an important role in reproduction of the European corn borer.

Studies at Ankeny, Iowa, on the irradiation of diapausing larvae of European corn borer have shown that pupation, moth emergence, and mating were nearly normal at levels of irradiation as high as 5000 rads. Egg hatch and numbers of eggs laid were most severely affected at 4000 and 5000 rads.

At Tifton, Ga., mating studies in which tepa-sterilized and fertile fall armyworm males were mated to normal females show that the sequence in which the matings occur is very important. Females, mated to a sterile male and then to a fertile male, oviposited 95% viable eggs, indicating that sterile sperm are not competitive with viable sperm. However, in the opposite mating sequence, results were not so clear. Oviposition from females mated to fertile males and then sterile males indicate an all or nothing type response. Approximately 45% of the females produced all sterile eggs after the second (sterile) mating while 45% produced all viable eggs.

At Tifton, immersion of fall armyworm pupae in a solution of tepa containing varying quantities of acetone sterilized some of the emerging moths, but 100% sterility was not obtained with any of the treatments. A marked reduction in egg-hatch occurred in practically all treatments, with a marked increase in mortality of pupae and emerging moths. Other studies were conducted in which larvae of the fall armyworm were reared on media impregnated with varying amounts of tepa. A toxic effect was noted in concentrations greater than one-tenth percent with an occasional sterile response in some of the lower dosages. The major response was mortality of the larvae and adults in some cases, indicating a toxic rather than sterilizing effect of the material. Nonsignificant differences were noted in the effect on the males versus females.

In the combination light trap-chemosterilizer studies at Tifton increasing the concentration of tepa to 0.6% increased its effective time, both in the wick and the reservoir, to beyond five days, indicating that this may be a technique for increasing the overall effectiveness of the feeder. However, laboratory experiments indicated that when the material was used at a concentration higher than approximately 0.5%, the tepa acted as a feeding repellent to the adult and they only fed whenever forced to through starvation. However, laboratory experiments indicated that some but not all fall armyworm would be sterilized when passing through the feeder.

Studies with the light trap-chemosterilant feeder were conducted with the corn earworm in Georgia and the effects of 0.15, 0.3, and 0.6% tepa solutions on field-collected earworms were recorded. The 0.15% solution

reduced but did not eliminate egg hatch in all instances when the material was held for as long as seven days in the field and bioassayed after each 24-hour period. The 0.3 and 0.6% concentrations reduced egg hatch and oviposition. Some increases were noted in mortality for each of the treatments, indicating that the material is toxic to corn earworm in higher concentrations.

A cooperative agreement with Auburn University, in which the sex attractant of the southwestern corn borer will be studied, is under way. More than 10,000 virgin females have been reared, abdomens clipped, and sent to Auburn for study.

Results of laboratory tests at Tifton, Ga., using excised corn leaf segments as a substratum indicated that an attractant made from a water extract of corn kernels mixed with the insecticide, Shell SD-8447, used at the rate of 0.5 ounce of active ingredient per 25 gallons of water, increased earworm larval mortality approximately 30% above that obtained with the SD-8447 spray alone. A water extract of silks increased mortality approximately 20%, while a water extract of leaves gave no apparent effect. No increased mortality was obtained when fall armyworm was used as the test insect.

At Tifton research has continued on sex pheromones of fall armyworm, Spodoptera frugiperda, corn earworm, Heliothis zea, and beet armyworm, S. exigua. In all three species the pheromone was found in the last abdominal segment. The pheromone of female fall armyworm moths was isolated in pure form and identified as cis-9-tetradecen-1-ol acetate. Its chemical structure was verified by synthesis. The pheromone is now being evaluated in the field for attractancy. This material did not excite males of corn earworm nor beet armyworm when tested in the laboratory.

A laboratory procedure has been worked out at Tifton for the collection and isolation of sex pheromone of corn earworm. Active fractions from both laboratory-reared female moths as well as from moths caught in light traps elicited copulatory attempts on males.

The crude extracts from each of the above-mentioned three species of insects are specific in eliciting a sexual behavior in the respective male moth. No overlap of activity has been obtained in laboratory assay. However, crude extracts of corn earworm and to a slighter extent crude extracts of fall armyworm elicited a reaction in males of cabbage looper, Trichoplusia ni.

In cooperation with Agricultural Engineers at Tifton, Ga., ultrasonics was evaluated for its effectiveness as a repellent to the corn earworm moth. The sound was beamed over a field with a 2-inch diameter LTV transducer which emitted sound waves at a frequency of 31 kc/sec up to a sound intensity of 84.5 db, as measured on a B&K sound meter on the B scale. The transducer was revolved at 324 rpm from 6 p.m. until 6 a.m.

during the tests. Effectiveness of the sound was determined by counting corn earworm eggs, and collecting moths near the transducer in light traps. There was no significant differences between the number of adults or number of eggs near the transducer and in the check area.

2. Small Grain Insects. The larvae of this false wireworm feed on small grain seed in the soil. Preliminary studies at Brookings, S. Dak., have indicated that chemosterilant impregnated wheat serves as a method of introducing these compounds into the larvae. Larvae feeding on 50 ppm tepa treated wheat were killed before pupation. Larvae treated with apholate and metepa at 100 and 500 ppm and with tepa at 100 ppm produced adults that laid few viable eggs. The chemosterilants did not significantly reduce the germination of wheat soaked in the chemicals.

Genetic experiments at Lafayette, Ind., showed that first generation progenies from reciprocal matings between individuals of the Great Plains race and Races A, B, C, and D of the Hessian fly reacted as Great Plains race in that they were able to infest Turkey but unable to infest Vermillion, Monon, and Knox 62, wheat varieties differing in their genes for resistance to one or more races of Hessian fly in the eastern soft wheat region.

These experiments point out the possibility that high density populations of the Great Plains race could be released in local areas in the eastern soft wheat region and theoretically reduce the wild type populations to insignificant numbers 4 to 5 generations after release.

Tests at East Lansing, Mich., showed that apholate was an effective chemosterilant for the cereal leaf beetle. A 0.05% aqueous concentration, applied as a dip, caused 100% sterility of both sexes. When only males were treated a 0.1% solution was needed to effect complete sterility. Longevity of treated males was reduced at the sterilizing dosage, death occurring mostly ten days after treatment. A ratio of treated males to untreated males of about 12:1 would be required to reduce egg viability to zero. Histological sections revealed no damage to the testis of males treated with 0.1% apholate.

An exploratory study of duTer (hydroxytriphenyltin) indicated that it was most effective as a chemosterilant when both sexes were treated. Concentrations of 2.0% and 3.0% caused lethargy, manifested by inactivity and starvation. At lower concentrations, these effects were progressively less pronounced.

Sterility, mating, feeding, and mixing tests were carried out with pre- and post-diapause irradiated cereal leaf beetle males. Irradiation at the pre-diapause stage induced a higher level of sterility than did exposure after the termination of diapause. Exposure levels of 4000 rads and above of beta, gamma, and x-ray significantly reduced feeding of irradiated males. Exposure of adult females at levels of 2000 rads almost entirely eliminated

the production of eggs while levels of 1000 rads resulted in reduced egg production and extremely low hatching percentages. Mixing tests in which males irradiated at 1000 and 2000 rads were mixed with untreated males in varying proportions and mated with untreated females were also carried out. Mixing ratios of nine males irradiated at the 2000 rad level to one untreated male paired with ten untreated females resulted in an over-all reduction in hatching potential of 75 to 84%. The introduction of a competition factor by the inclusion of only a single female caused a further hatching reduction of the magnitude of 5%. Mating tests in which the untreated male and the untreated female were marked indicated that the reduction in mating vigor of males exposed to 2000 rads of beta irradiation is in the region of 7%.

Screening of synthetic materials for use as chemical attractants for the cereal leaf beetle was continued during the past year. None of the candidate materials elicited a response in the cereal leaf beetle.

Wheat stem sawflies, most of which were in the pupal stage of development, were exposed to gamma ray radiation at eight dosage levels ranging from 2,000 to 110,000 rads at Fargo, N. Dak. Reduction in adult emergence was slight at levels below 10,000 rads, treatments of 70,000 and 110,000 rads caused reductions of 59 and 85%, respectively.

Post diapause wheat stem sawfly larvae were exposed to gamma ray radiation at levels ranging from 500 to 3000 rads. Increased dosages reduced the amount and delayed the time of sawfly emergence. These effects were slight at the lowest level (500 rads) but amounted to over 50% reduction in emergence and a three day delay in the 50% emergence point at the highest radiation level (3000 rads). The mean longevity of emerged sawfly adults was reduced from 6.1 days for the non-irradiated larvae to 4.1 days at the 3000 rad treated larvae.

In cooperative studies with Georgia Tech methods are being developed to study the dielectric constant of the exoskeleton of insects to determine if insect spines act as waveguides.

In research conducted under contract with Michigan University electromagnetic attraction studies performed with incoherent radiation sources revealed no gross attraction characteristics with either the corn earworm or fall armyworm.

Studies are being conducted under a cooperative agreement with the Electronic Research Laboratory at the University of California on irradiating insects with narrow band coherent frequencies in the infrared and microwave region to test response of these insects to coherent radiations. Under this same project methods for duplicating infrared and microwave lines from organic chemical scents are being developed.

F. Evaluation of Equipment for Insect Detection and Control

A pneumatic spraying system, developed by the agricultural engineers at Tifton, Ga., was evaluated. Pneumatic nozzles applied 1 and 2 pounds malathion and the 650017 nozzle, 2 and 4 pounds of malathion per acre. Analysis of plants immediately after application indicated residues of 13 and 26 ppm when the F-1 nozzle was used to apply 1 and 2 pounds per acre applications, respectively. Residues of 311 and 825 ppm with 2 and 4 pounds per acre applications, respectively, were obtained with the 650017 nozzle.

In preliminary studies at Tifton, Ga., a modified centrifugal fan in a light trap was compared with gravity light traps. The percent increases in the fan trap catch over the gravity trap were: Granulate cutworm, 19; lesser cornstalk borer, 34; fall armyworm, 56; tobacco budworm, 136; corn earworm, 196; tomato hornworm, 203; tobacco hornworm, 285; and armyworm, 429.

In cooperation with agricultural engineers at Tifton, Ga., a Dynafog aerosol generator was tested for control of the earworm. DDT was fogged directly into the corn each day during the silking period. When the corn ears reached optimum roasting ear stage, they were evaluated for insect damage. About 90% of the ears treated were marketable, which was about equal to DDT applied by conventional spray equipment.

A study designed to develop improved equipment for applying insecticides was continued at Tifton in cooperation with the Agricultural Engineering Division. An experimental duster for research purposes was designed that did not vary in output more than ± 2% between applications. A round and rectangular air curtain nozzle was used with the dusting machine with or without an electrostatic charge. The electrostatic charge was set up between the high potential electrode centered about 1-1/2 inches in front of the center nozzle and the outer nozzle. This equipment was compared with a sprayer for corn earworm control. There were no differences in control between any of the dusting nozzles and the conventional sprayer. Ultra-low volume sprayers (1/2 pint to 2 pints per acre) have been modified and tested for corn earworm control. Preliminary data with this equipment show that the flat spray pneumatic nozzle and the flat fan 65° nozzle above the plants were not adequate for insect control. When the nozzles were placed equidistance at ear-height between the rows, insect control was improved. To further improve insect control, an electrostatic charge was placed on the spray particles. To effectively place a charge on the particles, the nozzle was placed inside of a 20 mph air stream. Tests with this equipment showed a significant improvement in insect control. However, later tests indicated that the improved control was due to the air blast and not the electrostatic charge.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. In continuing tests at Ankeny, Iowa, to locate additional sources of first brood resistance to the European corn borer, 14 of 73 South

Carolina inbred lines of dent corn had a satisfactory degree of resistance. Most of the 32 heterozygous composites, which were derived from crosses obtained from the Rockefeller Foundation were highly susceptible. Two of 14 inbred lines with a fair degree of corn rootworm resistance had a good degree of resistance to the European corn borer.

The value of a recurrent selection technique in selecting for resistance to leaf feeding by the European corn borer has been determined. A group of S_1 lines from five original populations (C_0) and the populations derived from three cycles (C_1, C_2, C_3) of selection in each variety were artificially infested in 1965 and 1966. Two cycles of selection were sufficient to shift the frequency of resistance genes to a high level in all varieties. Three cycles of selection produced essentially borer-resistant varieties.

Ninety-eight of 313 S_1 lines from a WF9 synthetic and 198 of 424 S_1 lines from a B14 synthetic had a satisfactory degree of resistance. Approximately 570 individual rows of lines in various stages of inbreeding were rated for leaf feeding resistance. These lines were derived from a variety of sources and represent most of the new lines under development in the corn breeding project.

One phase of the European corn borer resistnnce program at Wooster, Ohio, is screening inbred lines of dent corn submitted by corn breeders from the Northern States of the North Central Region, for resistant germ plasm. In 1966 the Michigan Experiment Station submitted 623 inbred lines which were screened for corn borer and leaf blight resistance; a considerable number of these lines indicated a good degree of resistance to the European corn borer but most of the lines were susceptible to the northern corn leaf blight fungus. Ten inbreds from Michigan that rated resistant to both the corn borer and blight in 1965 were re-evaluated for corn borer resistance in 1966; eight of these rated resistant and two intermediate in resistance.

Seven of 19 inbreds which had previously been selected for tolerance to mazie dwarf mosaic had a good degree of resistance to the European corn borer.

Studies have been continued at Ankeny, Iowa, on the biochemical factors responsible for corn resistance to the European corn borer. It was found that the compounds, 2,4-dihydroxy-1,4-benzoxazin-3-one (DIBOA) and 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA), are produced by germinating corn seeds. DIMBOA concentration in the coleoptile of inbred WF9 (susceptible) is 40X greater than that found in the whorl tissue of the older plant, while DIBOA concentration is 45X greater. In inbred CI.31A (resistant), the DIMBOA concentration of the coleoptile is 5X greater than that found in whorl tissue of older plants, while DIBOA concentration is 7X greater. Radicles of both inbreds contain DIMBOA at a concentration of 5 to 6 mg/g dry tissue and DIBOA at 0.4 to 0.6 mg. DIBOA and DIMBOA are

biosynthesized by the plant upon germination and throughout development of the plant. These compounds apparently play an important physiological role in plant development.

A genetic study of the character high benzoxazinone content in single crosses is underway. Preliminary data show that high benzoxazinone content appears to be a dominant character while low content is recessive. Resistance ratings for the single crosses correlate with benzoxazinone concentration. Concentration in resistant single cross hybrids is ten times greater than that found in susceptible hybrids. Thus, level of corn borer resistance in single cross hybrids and inbreds can be predicted by chemical analysis. Such chemical analysis may be of value as a screening tool for resistance in corn breeding programs devoted to the development of superior hybrids with more satisfactory corn borer resistance.

In Mississippi southwestern corn borer resistance studies of 34 dent corn commercial hybrids, one experimental hybrid and 29 single crosses showed no significant differences among hybrids based on percentage of infested and/or girdled plants. Greenhouse studies were conducted to determine the susceptibility or resistance of eight inbreds to the southwestern corn borer. Four of the inbreds were southern (Mp414, SC 149, F_6, F_{44}). The other four were northern inbreds (B 49, CI31A, B 37, WF9). B 49 and CI31A are highly resistant to the European corn borer. B 37 and WF9 are highly susceptible to European corn borer attack. The results showed all eight inbreds to be susceptible to the southwestern corn borer.

Of 62 hybrids evaluated for rice weevil resistance at State College, Miss., several showed good resistance. Kernel infestation ranged from 1.0% in Pennington 7-C-11-A to 46.5% for PAGS x 59 and Funk G 4703.

Twenty-five corn hybrids were rated for corn earworm damage at Temple, Tex. All were badly damaged. Texas 30 and Texas experimental hybrid 6689 had the least amount of damage with .63 inch penetration of the ears and 90 and 93% of the ears infested.

Twenty-seven commercial hybrids and 9 Texas experimental hybrids were rated at College Station for earworm damage. Texas 36A with an average earworm penetration of .23 inch with 73% of the ears infested was the most resistant. Ten experimental white hybrids out of 15 at Baton Rouge, La., showed high resistance to the corn earworm. The best hybrid was La. experimental 6119 with an average penetration of .17 inch and only 57% of the ears infested.

Corn lines selected for varying chemical content were evaluated for corn earworm and fall armyworm resistance at Tifton, Ga. In a field test, corn kernels with low amylose content seemed to have more earworm damage than kernels with high amylose content. In addition, kernels with high lipid or high carotene content had more damage than kernels with low lipid

or low carotene. A second part of this test involved a fat analysis of larvae reared on these same corn lines. Indications are that larvae reared on the low amylose corn lines contain the least fat, while larvae reared on the high protein lines contain the most fat. Larvae from the high lipid line contained more fat than larvae from the low lipid line. The opposite was true for the high and low carotene lines.

Corn inbreds 81-1 and 471-U6 make up the desirable and earworm resistant sweet corn "Walter's White" and are difficult to maintain and use in a crossing program. Several hybrids made from inbreds produced in a backcrossing program with 81-1 and 471-U6 have shown considerable promise in retaining quality and earworm resistance. Improvement has been made in vigor and shortening the silking date of the 81-1 backcrosses, at least as inbreds. Improvement has also been made in 471-U6 backcrosses as to ease of handling in a hand-pollination program.

A study of the relationship of corn earworm damage with ear husk tightness and larval development indicated highly significant differences among corn lines for husk tightness, depth of larval penetration, and larval weights (seven days after infesting). A highly significant negative correlation coefficient (r=-.513**) indicated a relationship between husk tightness and depth of larval penetration. Husk tightness and larval weights from field ears had a highly significant negative correlation (r=-.582). Depth of larval penetration in the field ears at seven days and larval weights from these ears showed a highly significant correlation (r=.541**).

At Tifton ten corn lines selected for varying chemical content were laboratory screened for rice weevil resistance. Highly significant differences existed among lines in the number and weight of the weevil progenies reared per line. The number of progeny and their respective weights were not significantly correlated. Lines PI 217413 (hard flint type kernels) and Wx 38-11 (low amylose) produced significantly fewer weevil progeny than did lines SC 249a (high lipid), CI 21 (low carotene), and Mp488 (high carotene). Line T-115 ae (high amylose) produced significantly more weevil progeny than did line Wx 38-11 (low amylose). Line SC 246c (high protein) produced heavier progeny than line SC 256 (low protein). A super sweet line produced the lightest progeny. Fat analysis of progenies reared on these lines ranged from an average of 201.8 µg per insect on line Wx 38-11 (low amylose) to 261.2 µg per insect on line Mp488 (high carotene).

Seventy-five corn lines containing germ plasm from Central and South American lines as well as germ plasm from a number of southern dent inbreds were laboratory screened at Tifton, Ga., for resistance to the rice weevil. Statistical analysis indicated that a highly significant difference existed among certain entries for the number of rice weevil progeny produced on these lines. The entry Eto x Manfredi R(2)1-1 appeared to be the most resistant to rice weevil within the conditions of this evaluation

while corn line entry P.R. 9D x CBC(2)1-1 appeared to be the most susceptible. The more resistant entries tended to have a relatively large number of kernels that were not damaged while the more susceptible entries tended to have few, if any, undamaged kernels at the end of 56 days after initial infestation.

Evaluation of corn lines for rootworm resistance was continued at Brookings, S. Dak. Nineteen S_2 and 13 S_1 corn lines survived a heavy rootworm infestation in the field in 1966. These lines have survived a number of tests over the past years. If their 1967 performance is equal to their previous ratings, some of the lines may be considered for formal release.

The 1966 performance of F_1 and S_1 lines provided added support that HD2187, SD10, B14, CI21E, and Mo22 are usually involved in the superior crosses. SD10 X B14 showed considerable promise in a number of tests.

Further evidence of progress in identifying and breeding for resistance to corn rootworm is shown by the poor performance of untested lines as compared with lines that have been retained from earlier tests. Over twice as many of the retest lines had a satisfactory rating as compared with the new material tested. Of the 90 plant introductions, only one was resistant.

In studies conducted under P.L. 480 project in India, techniques for measuring the resistance of corn to the borer, Chilo zonellus, have been developed, and some varieties were found with a moderate degree of resistance to this borer.

In research conducted at Ames, Iowa, under a research grant, two previously unreported cyclic amides related to the cyclic hydroxamix acids have been isolated from the corn line 31a. A method for labelling DIMBOA and DIBOA with carbon 14 was developed and a method for estimating the amount of DIMBOA in corn was found.

Research is being conducted under a cooperative agreement with the Missouri Experiment Station on the nature of corn earworm resistance in corn. The length of silk channel has been determined as an important factor contributing to resistance of inbred lines.

2. Small Grain and Sorghum Insects. At Bozeman, Mont., spring wheat varieties were screened to find wheats resistant to sawfly under all environmental conditions. One variety P.I. 94585 and selections from this variety have a stem solidness character which is more stable under varying environmental conditions than the resistant variety, Rescue.

At Fargo, N. Dak., it was determined that the main effects of wheat variety, time of planting, and time of sawfly oviposition on sawfly infestation and damage are separable. The number of elongated internodes

is a function of wheat variety and planting date. The number of elongated internodes influenced oviposition rates and sawfly infestation or damage. Associations between stem elongation and other plant characters were determined.

At Minot, N. Dak., no inter-row preferences for oviposition among rows of wheat bordered or not bordered by a wheat stem sawfly susceptible variety of wheat could be determined. Differences in rates of oviposition were the result of differences among varieties in the number of elongated internodes and other factors at the time of sawfly flight and oviposition. Oviposition and damage were not influenced by the sequence in which the varieties were planted or by the presence or absence of an adjacent row of a sawfly susceptible wheat. This information is important in both the biological and statistical senses because it demonstrates that the sequence of varieties in single row plots of multi-variety plantings does not influence sawfly oviposition or damage.

At Brookings, S. Dak. a test, screening 66 varieties of spring and durum wheat for resistance to the wheat stem maggot, indicated that the hard red spring wheats: Pembina (C.I. 13332), Kenya 184 X Wisc. 250 4 (C.I. 13588) and Crim (C.I. 13465) and the durum wheats: North Dakota Sel. 58-274 (no C.I. or P.I. number), RL 3394 (C.I. 13583), and Yuma (C.I. 13245) may possess some resistance to the wheat stem maggot.

At Stillwater, Okla., it was determined that greenbug-resistant Will barley maintained resistance to greenbugs from various sources and to all strains both under laboratory and field conditions. The factor responsible for resistance in barley, apparently, is different from that in wheats because wheats which were formerly resistant are now susceptible to the several greenbug strains.

At Stillwater 14 greenbug-resistant oat selections were retested, 13 were susceptible to the new greenhouse strain. One of the entries, P.I. 186270, Avena Selecta M.C. 41374 I.F., from Argentina, which had been reported in 1961 as being one of the most resistant oats to the "normal" greenbug strain, was also resistant to the new biotype. Crosses involving this oat with resistance to both greenbug biotypes are being made.

In studies conducted at Stillwater under cooperative research agreement, it was found that a greenbug susceptible barley variety Rogers contained 1-1/2 times as much ninhydrin as resistant variety Will. In this project progress has been made in developing a bioassay method of evaluating plant extracts and in obtaining salivary fluids and honey dew from grain aphids for chemical analyses.

The 1966 Indiana Hessian fly survey showed that Race B field populations of Hessian fly, capable of infesting Dual, Monon, Redcoat, Reed, and Riley wheats having the H_3 resistance, continue to be a threat to these varieties although the average infestation for the State was slightly lower

than last year. Samples from 317 certified wheat fields showed 69% of them to be infested as compared to 84% last year. Knox 62, having the H_6 gene for resistance, continues to remain comparatively uninfested, with an average infestation for the state being less than 1%, whereas varieties carrying the H_3 gene averaged 7.6%. Benhur, released this year, also has the H_6 gene for resistance and is also expected to suppress the fly populations in areas where it is planted.

In lower Michigan, Hessian fly infestations during the crop year 1965-66 decreased considerably from the previous year. Samples from 175 certified wheat fields showed 38% of the fields to be infested with Hessian fly. The average infestation for wheats having no Hessian fly resistance was 2.3%, and 2.2% for wheats having the W38 resistance. The racial composition of two populations showed Race A to be the predominant race, but Races B and D, which are capable of infesting W38 and PI 94587 resistant varieties, were present in small numbers.

Wheat varieties resistant to Hessian fly are widely used in the critical area of North Central and Northeastern Kansas but serious reductions in their use has occurred in some counties. The resistant varieties, Gage, Warrior, and Parker which are now available should result in increased acreage of resistant varieties.

Wheat breeding material from four State Experiment Stations in the eastern soft wheat region and three State Experiment Stations in the hard red wheat region were evaluated for Hessian fly resistance at Lafayette, Ind., and Manhattan, Kans. Approximately 11,500 lines, hybrids, varieties, or selections were included in these tests. Wheat reactions to Hessian fly were recorded and forwarded to wheat breeders involved, and in some instances resistant plants were air mailed to wheat breeders for further selection or crossing.

Approximately five and one half thousand head selections, hybrids, and lines from the Purdue regular fly nursery, preliminary yeild nursery, advanced yield nursery, fly stem rust nursery, and Septoria nursery were evaluated for resistance to Races B and D. All wheats have one or more of the H_3, H_5, H_6, or Marquillo genes for resistance in their parentage. Many of the F_2 and backcross lines containing the H_5 gene in combination with one or more of the H_3or H_6 genes were saved, vernalized to break the winter habit, and utilized in the crossing program in the greenhouse. Two Hessian fly resistant soft red winter wheats were released by the Indiana Experiment Station in cooperation with the Entomology and Crops Research Divisions: Riley 67, an improved wheat having the H_3 gene for resistance, and Benhur, having the H_6 gene for resistance to Races A and B.

At Lafayette, Ind., experimental populations of Hessian fly are being studied to determine differences in natural fitness in Hessian fly races when reared on a non-resistant variety offering no selection and to determine the effectiveness of selection by resistant varieties in changing the

gene frequency of populations. Intensifying selection by gradually increasing W38 resistant plants to 100% of the plant population has changed the initial frequency of .95 Race A and .05 Race B in the first generation to .1 Race A and .9 Race B after eight generations. No significant change has occurred in the initial frequency of .95 Race A and .05 Race B of control populations reared on a non-resistant wheat.

A new race of Hessian fly, Race E, has been isolated from a population of Hessian fly collected in Georgia. This race differs from all known races in that it is capable of infesting wheats susceptible to Race B but is unable to infest wheats susceptible to Race A.

The first emergence of Hessian fly from stubble collected in western Kansas is predominantly the Great Plains race of fly. If this first greenhouse population is carried through on a continuous development basis, it quickly shifts away from the Great Plains race and becomes predominantly Race A or B. If, however, this first greenhouse population is put in the refrigerator from three to six months before it is used, the percent of Great Plains race of fly that will emerge is greater than when reared on a continuous development basis, but it is still not as high as the original material.

Work was continued in Michigan and Indiana on the evaluation of wheat, oats, and barley for resistance to the cereal leaf beetle. Successful crosses have been made between cereal leaf beetle resistant wheat varieties and adapted hard red winter wheats, hard red spring wheats, soft winter wheats, and durums. In the 1967 field tests 29 F_4 progenies from crosses with the spring variety Crim and 62 F_4 progenies from crosses with the spring wheat Chris had only trace amounts of cereal leaf beetle damage under a heavy infestation. In this same test 211 F_4 winter lines showed a high degree of resistance.

At Purdue breeders have used pubescent spring and winter wheats Agropyron sp. and Triticum persicum, as resistant parents crossed with Hessian fly resistant adapted wheats. Michigan workers have introduced resistance to the beetle into 23 crosses involving commercial varieties or advanced lines.

There are no highly resistant oats to the cereal leaf beetle, but two lines C.I. 7495 and C.I. 4991 have shown some resistance.

There are three or four lines of barley that have a good degree of resistance to the cereal leaf beetle. These include C.I. 6469, C.I. 6671, and C.I. 12225.

Greenhouse techniques have been developed at East Lansing, Mich., to evaluate cereal leaf beetle resistance in small grains. These methods include rate of larval growth, adult feeding preference and adult oviposition preference. By using these methods, lines of winter and spring wheats were isolated which are highly resistant to the cereal leaf beetle.

These lines included C.I. 8519, 8529, 8520, 9321, 9320, 9294, P.I. 280446, 238405, and 182750. Spring barleys (C.I. 6671 and 12225) and oats (C.I. 7495 and 4991) have also been found to possess some resistance to the beetle.

Resistance to the cereal leaf beetle in wheats is related to the amount and type of leaf pubescence. Pubescence has a three-fold effect on the beetle, acting as a deterrent to oviposition, promoting desiccation of eggs, and inhibiting first instar larval feeding.

Barley and oat resistance is related to non-preference for oviposition.

At Tifton, Ga., 30 sorghum lines were evaluated in greenhouse tests for resistance to fall armyworm larval feeding. Results indicated highly significant differences among lines rated for leaf feeding as well as the number of larvae found per plant. There also was a significant positive correlation (r=0.38) between damage ratings and the number of larvae recovered per plant. A low correlation (r=0.12) between damage ratings and larval weights resulted.

Grain sorghum leaves (30 days after planting date) and heads (10 days after 50% bloom) were harvested from each of 10 lines, lyophilized, and incorporated into an agar-chromic oxide diet. Each diet was bioassayed for percent utilization by fall armyworm larvae. Results indicated a range in utilization from 13.2 (low) on line CI 623, a Feterita, to a high of 36.8 on line SPI 34911, a Hegari. Both of these entries are dual grain forage sorghums. The only forage sorghum in the test, FC 13614, had low utilization while the grain sorghum FC 8913 had comparatively high utilization by fall armyworm larvae. Percent utilization of leaves showed a smaller range (27.9-39.7) among entries than was shown by the heads. Again, the forage type had low utilization.

Grain from 84 sorghum lines was evaluated for rice weevil resistance at Tifton, Ga. The number of weevil progeny produced on each line after being infested with parent weevils was recorded and a fat analysis was determined for weevils reared on the various lines. Results indicate a range of 0.8 progeny per female on line CI 580, a broom corn, to 32.0 progeny per female on line TS 23240, a Kaoliang. In general, the broom corn and sorgo types produced the fewest progenies while the Kaoliang and kafir types produced the most. Differences in number of progeny per female and fat content of progeny reared on the various lines were significant at the 1% level. Range of fat content per insect varied from 4.15% on ODC (midge resistant lines from South Africa) to 11.88% on FC 9111 (orange).

Two-hundred-and-nine sorghum lines were evaluated in the field for resistance to the sorghum midge. Average midge emergence per head ranged from a low of one per head on 15 lines to a high of 20, or more, per head on 52 lines. Lines of particular interest from a resistance standpoint are: CI 623, SPI 34911, SA 1595, Wiley, CI 27, WD 623 x 807-18, SA 310, FC 8728, FC 16205, CI 918, HC 617, FC 8986, Reliance, and ODC 19.

At Stillwater, Okla., 144 sorghum varieties were manually infested in the early whorl stage of plant development with corn earworm, fall armyworm and southwestern corn borer eggs in the "black-head" stage to test them for resistance to these insects. Nineteen showed resistance to the corn earworm and 61 to the fall armyworm. Southwestern corn borer resistance was shown by 12 of 75 entries.

In Zaria, Nigeria, one sorghum line was found that showed tolerance to the sorghum midge.

H. Insect Vectors of Diseases

1. Corn Insects. A nonpersistent virus was isolated from naturally infected field corn at Brookings, S. Dak., during the 1966 growing season. The virus reacts like brome mosaic virus (BMV) in certain aspects of its symptomology and host range. However, it has not proven to be infectious in garden beets, cucumber, tobacco, or snap beans, all of which are reported as hosts of BMV. Preliminary investigations have shown that several monocotyledonous plants, i.e., barley, Hordeum vulgare; wheat, Triticum aestivum; corn, Zea mays; yellow bristlegrass, Setaria lutescens; and barnyard grass, Echinochloa crusgalli, develop systemic infections of the virus when they are mechanically inoculated with whole freshly extracted sap from corn. The symptom syndrome produced by infections of the virus in Golden Bantam sweetcorn is progressive from lenticular local lesions on the inoculated leaves to a systemic infection resulting in wilting and tip necrosis of the whorl leaves, to collapse and death of the seedlings within 10-14 days after inoculation.

Vector tests with the greenbug, corn leaf aphid, apple grain aphid, English grain aphid, and the green peach aphid have been negative.

In Mississippi many inbreds, single crosses and double crosses including widely grown commercial hybrids were evaluated for corn stunt virus infection. Resistance or susceptibility was apparent in all corns rated. Fortunately, there is a high degree of resistance in many of the commercially established hybrids.

Transmission efficiency of the apple grain and English grain aphid was studied at Brookings, S. Dak., after aphids fed through a Parafilm membrane on suspensions of barley yellow dwarf (BYDV). Transmission of BYDV after feeding on virus-containing sucrose or complex diet solutions was generally low and variable. Rhopalosiphum padi was more efficient than Macrosiphum avenae. Increases in acquisition feeding periods did not result in a corresponding increase in virus transmission or numbers of stylet sheaths formed in solutions. Greatest numbers of stylet sheaths were counted in diet preparations.

At Brookings, S. Dak., field plots of 35 hard red spring wheats infected 100% with BYDV showed yield losses above 50%. Highly significant differences

between healthy and diseased and between varieties were reflected in yield, height, and maturity.

Research conducted under cooperative agreement at Wooster, Ohio, has shown that the wheat curl mite, Aceria tulipae, secretes a phytotoxin that causes kernel red streak of corn. Some lines are more sensitive to the toxin than others.

Studies on the transmission of corn viruses by aphids and leafhoppers is being conducted under a research grant by the Missouri Experiment Station. Mass rearing techniques have been developed to rear several species of leafhopper for large-scale transmission tests. One insecticide, Niagara NIA-10242, has shown promise in controlling the vectors.

Research has continued at State College, Miss., under a research grant to determine the role of leafhoppers in the transmission of corn stunt. Dalbulus maides, one of the vectors migrates into the United States each year from Mexico. Graminella nigrifrons, another vector is the most abundant species in corn. Gammagrass has been proven a host plant for both of these vectors. At least 35 species of grasses are host of the corn stunt virus.

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AREA NO. 8. RICE INSECTS

Problem. Several species of insects including leafhoppers, the rice stink bug, rice water weevil, grape colaspis, stalk borers, and the sugarcane beetle damage rice in the rice-growing areas of the United States. Progress has been made toward the solution of some of the insect problems encountered in the production of rice but more effective, more economical, and safer insect control measures are needed. The appearance of resistance to certain insecticides in some rice insects stresses the need for basic information to overcome this problem. Additional emphasis should be given to new approaches to control rice insects and to evaluate rice varieties for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAM

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Experiment Station. Basic research on the control of damage by larvae of the rice water weevil, Lissorhoptrus oryzophilus, by increasing plant tolerance, is being conducted under a grant with the University of Arkansas, Fayetteville, Ark. Under PL 480, A7-ENT-5, India, a survey is being made of the natural enemies of pests of paddy.

The Federal scientific effort devoted to research in this area totals 1.2 scientist man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.4 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; and 0.2 to program leadership. In addition Federal support for research in this area provides for 0.4 man-year in a research grant to the University of Arkansas for varietal evaluation of rice for resistance to the rice water weevil.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 3.3 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

At Baton Rouge, La., investigations have been continued on the biology of the rice water weevil. Photoperiod, water temperature, and light intensity were found to be factors involved in the reproduction of this insect. The

optimum condition for maximum reproduction as found in the greenhouse study, was a 14-hour day-length, 85° F water temperature and at least 3300 foot candles of light. Adult weevils removed from bunch grass during the winter copulated within minutes after emerging and oviposited within 6 days. Egg hatch averaged 4-1/2 days, larva matured within 21 days and adult emergence occurred within 26 days.

A newly initiated study of the seasonal history and flight activity of the rice water weevil and green rice leafhopper, Draeculacephala portola, using light traps, yielded data showing three population peaks for the rice water weevil during the spring and summer of 1966. These data support previous observation reports of 3 summer generations annually. These data also indicated that night temperature influences the flight activity of this insect and activity ceases with a temperature decline to 63° F or below. A laboratory study supported these findings where the adult weevils became almost completely immobile at 60° F. This information has provided a means for retaining large numbers of the adults for winter studies in the greenhouse and laboratory. From these data it appears that four or more summer generations of the green rice leafhopper occur with the third and fourth generations overlapping.

A study consisting of weekly sampling of bunch grasses from November 10, 1966, to May 15, 1967, for adult rice water weevils revealed low mortality occurs during overwintering. The sex ratio of the overwintering population until about April was almost 1:1 but after April 1, the sex ratio shifted to about two females for each male in overwintering quarters.

Overwintering counts taken throughout the winter on stem borers, Chilo plejadellus and Diatraea saccharalis revealed low mortality occurred in rice stubble.

B. Insecticidal and Cultural Control

Low volume concentrate malathion at the rates of 5 and 9 oz was tested against the rice stink bug, Oebalus pugnax. Neither of the LVC rates were effective as the 0.5 pound emulsifiable concentrate spray. At the 9 oz rate the LVC appeared to be effective against nymphs but not against adults. The 9 oz rate provided effective control of grasshoppers and green rice leafhoppers.

Eleven candidate insecticides alone and five in combination with aldrin were compared with aldrin seed treatment in 1966, for rice water weevil control, but none gave adequate protection. Some interaction occurred between propanil, a herbicide commonly used in grass control on rice, and many of the seed treatments with phosphate or carbamate insecticides. This interaction was characterized by leaf burn on seedling rice and subsequent yield loss where 25% or higher leaf burn occurred.

Six candidate insecticides were compared with aldrin as a granular application, post flood. Only Niagara NIA-10242, at the 1/4 and 1/2 pound toxicant per acre rate, and Bay 25141 at the 1 pound or higher gave satisfactory control.

C. Varietal Evaluation for Insect Resistance

Three nurseries, the Uniform Yield Nursery, Arkansas Disease Nursery, and International Blast Nursery, containing a total of 490 varieties or selections were evaluated for host plant resistance to the rice water weevil and the two stem borers, Chilo and Diatraea. No significant differences were found in resistance of these varieties/selections to any of the insect pests.

Research was conducted by the University of Arkansas under research grant to determine if the feeding site of the rice water weevil adult was associated with plant nutrients. Chemical analyses of leaves from each leaf position of rice plants ranging in age from 12 to 52 days were compared with adult feeding activity on the respective leaves. The preferred feeding site of the adult could not consistently be associated with changes in the level of the 12 plant constituents analyzed from the various leaves.

D. Insect Vectors of Diseases

At Baton Rouge, La., virus acquisition was determined for 9 to 10 day old adults of Sogata orizicola, which were the progeny of reciprocal crosses of hoja blanca virus (HBV) transmitters to non-transmitters. During nymphal development these adults were exposed at various lengths of time to diseased rice leaf tissue to allow them to feed. Planthoppers exposed to HBV diseased plants for short periods did not show any appreciable difference from individuals that had not been exposed to the virus. It appeared that the virus is primarily acquired transovarially from the female parent.

Individuals that acquired HBV transovarially had a decreased adult longevity; however, the total life span of insects that were progeny of HBV transmitting females was not significantly different from the progeny of non-transmitters.

Adults, 9-10 days old, were mated in all possible combinations of HBV transmitters to non-transmitters. The number of eggs resulting from these different matings were not significantly different.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Insecticidal and Cultural Control

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AREA NO. 9 COTTON INSECTS

Problem. The control of insects is a major cost in the production of the cotton crop. Although current insecticide control measures for cotton pests have been effective enough to keep growers in the cotton production business, improvements are needed in the safety of their use, in their efficiency, and in the reduction of undesirable residues on subsequent as well as adjacent crops or forage areas. Since 1947 when organic chemicals began to have wide usage on cotton, twenty species of cotton pests have developed resistance to certain insecticides emphasizing the need for developing basic information to solve or avoid the problem and to develop other methods of control that are more effective, economical or desirable. More research on approaches to control such as the sterile male or female techniques, repellents, sex and other attractants, biologically active compounds from the cotton plant, biological control agents such as pathogens, parasites, and predators, and safer insecticides and more effective ways of applying them is needed to develop improved methods of control. Methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The natural sex attractant of the pink bollworm and the synthesized compound, propylure, should be investigated thoroughly to determine their potential in the detection and control of this pest. The pink bollworm was found in limited areas in California for the first time in 1965 and injurious infestations occurred in some localities in 1966. In recent years the boll weevil extended its range to West Texas and poses a threat to cotton in New Mexico. A boll weevil that attacks cotton in northwestern Mexico and Arizona poses a threat to cotton production in New Mexico and California. It was found in California for the first time in 1965. However, none were found there in 1966. More knowledge is needed on the biotic potential of various pests and on factors that influence it. This information could serve as a basis for advising growers when control measures for the various pests will or will not be required and for determining the time when eradication or control programs should be initiated. The control of such insects as Heliothis spp. should be developed on an across the crop and host basis rather than by commodoties.

USDA AND COOPERATIVE PROGRAM

Research on cotton insects is conducted at field laboratories at Florence, S. C.; State College, Miss. with satellities at Stoneville, Miss. and Tallulah, La.; College Station, Texas; Brownsville, Texas, with a satellite at Waco; Tucson and Phoenix, Arizona; and Baton Rouge, La.

Various aspects of research being conducted are as follows: (1) studies on the biology, ecology, physiology, and nutrition of such insects as the

boll weevil, bollworm, tobacco budworm, pink bollworm, cabbage looper, beet armyworm, lygus bugs, and salt-marsh caterpillar; (2) studies to determine the mode of action and fate of various chemicals in and on such insects as the boll weevil and bollworms and their relationship to the development of resistance to insecticides; (3) studies to discover and develop more effective conventional and systemic insecticides and to improve methods of applying them to increase their efficiency in controlling various cotton pests; (4) studies to discover pathogens or other biological control agents including parasites and predators and to develop methods for using them to control the boll weevil, bollworm, tobacco budworm, cabbage looper, and other cotton pests; (5) studies to discover and develop cotton varieties resistant to or tolerant of attacks of such pests as the bollworm, tobacco budworm, cabbage looper, pink bollworm, boll weevil, cotton aphid, and spider mites; (6) studies to develop the sterile-insect release technique and procedures for using it alone or in combination with other methods for controlling or eradicating the boll weevil and pink bollworm; (7) studies to develop practical methods of employing biological active compounds such as the attractant, feeding stimulant and repellent in the cotton plant for the boll weevil, and sex and other attractants for controlling the boll weevil and other cotton insects; and (8) development or improvement of equipment for insect control such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill machinery, light traps, ultrasonic, and electronic devices.

The research is conducted in cooperation with the Agricultural Experiment Stations of South Carolina, Mississippi, Louisiana, Texas, and Arizona and with the Plant Pest Control, Crops Research, Soil and Water Conservation Research, and Agricultural Engineering Research Divisions, ARS, USDA. Research is also supported by grants, contracts, or cooperative agreements with Texas, Mississippi, California, Arkansas, Georgia, and Alabama Agricultural Experiment Stations, and the Southern Research Institute.

The Federal Scientific effort devoted to cotton insects research totals 56 scientist man-years. Of this number 20 are devoted to basic biology, physiology, and nutrition; 14 to insecticidal and cultural control; 6 to biological control; 6.5 to insect sterility, attractants, and other new approaches to control; 1.5 to evaluation of equipment for detection and control; 4.5 to varietal evaluation for insect resistance; 0.5 to insecticide residue determinations; and 3 to program leadership.

In addition Federal support for 4.0 man-years of research in this area is provided in contracts and grants. Of this total 0.9 is devoted to basic biology, physiology and nutrition; 2 to biological control; 1.7 to insect sterility, attractants and other approaches to control; and 0.4 to evaluation of equipment for detection and control.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 32.2 professional man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Boll Weevils. In 1967, spring woods-trash examinations for boll weevils were made in Central Texas, Northeast Louisiana, Delta and Hill sections of Mississippi and in four areas in the Carolinas. Comparative survival since 1962 in various areas was as follows:

	Weevils Per Acre				
Area	1963	1964	1965	1966	1967
Central Texas	452	97	4925	1098	1292
Northeast Louisiana	121	1049	3052	247	2057
Mississippi	13	289	995	1425	1525
South Central South Carolina	914	753	1855	484	3899
Coastal Plains, North and South Carolina	1560	2742	10164	3307	1542
Piedmont, North and South Carolina	350	134		3469	1801
North Central North Carolina	161	107	1371	1425	645

Survival was higher in 1967 than in 1966 in Central Texas, Northeast Louisiana, Mississippi, and South Central South Carolina. It was lower in the Coastal Plains of North and South Carolina, in the Piedmont of North and South Carolina, and in North Central North Carolina. These studies were made in cooperation with Plant Pest Control personnel in North and South Carolina and Mississippi.

Tests by the Tucson, Arizona laboratory with plastic spheres from a thurberia cotton growing site in the Santa Rita mountains indicated that extremely heavy rains would be necessary to float thurberia bolls containing weevils into cultivated cotton areas. Three hundred plastic spheres about the size of ping pong balls were placed in an arroyo 4.5 miles above the mouth of the Santa Cruz River near Amado, Arizona, on August 1. Rains of 2 inches between August 8 and 17 floated the spheres from the points of placement. One hundred fifteen spheres were recovered. The maximum movement was 2.5 miles and the minimum 200 yards. Preliminary results indicate that water transport of weevils in bolls from wild cotton to cultivated cotton is not very likely to occur.

Surveys by the Tucson laboratory showed that boll weevil complex populations were light and scattered in Arizona in 1966. Only one known infestation was of economic significance. Infestations did not develop in areas of severe infestation in 1965 because stub cotton was not grown in 1966.

Previously mated male boll weevils were less effective than unmated in fertilizing virgin females in laboratory studies at College Station, Texas. Egg production, egg hatch and percentages of eggs laid inside the squares were reduced when males had been previously mated several times.

Thurberia weevils survived up to 12 days in thurberia bolls submerged in water in studies at Tucson. High percentages of thurberia weevils survived in bolls soaked continuously in running water for 8 days. Small percentages survived up to 12 days. Although the surviving weevils were lethargic when removed from the bolls, they quickly recovered. When the soaked bolls were placed on sand heated to 100° F, there was little weevil mortality and virtually no emergence from the bolls. Thurberia weevils emerged from thurberia bolls soaked in water for one hour and dried at 110°F. Weevils, also, emerged from bolls soaked two and four hours and dried thereafter. Fifty and 80% of the weevils were freed after 3 and 5 soakings, respectively. Alternate wetting and drying of the bolls apparently freed the majority of the weevils but a small percentage escaped by chewing directly through the boll wall.

Diapausing hibernating weevils responded to moisture in laboratory studies at Tucson. Thurberia weevils freed from bolls were readily attracted to moist niches in laboratory tests. If this response to moisture is a behaviorial trait of the boll weevils, it could greatly enhance survival of the insect in hot, dry areas.

Preliminary data in studies at Tucson indicated that individuals of the boll weevil complex in summer generations lived an average of 5-8 weeks. Males tended to be longer lived than females. Females preferred bolls to squares as oviposition sites and laid an average of about 20 eggs.

In studies at the Boll Weevil Research Laboratory, overwintered boll weevils did not move from one cotton field to another after leaving winter quarters. In a field study conducted in Carroll County, Mississippi, 1588 overwintered weevils were marked in a test area 3 miles wide and 5 miles long. None of the 854 weevils collected in fields in which weevils had not been marked were marked indicating that there had been no inter-field movement. An estimated 25% of the total weevil population had been sampled. Indirect evidence strongly suggests that dispersal of overwintering boll weevil populations occurs in winter quarters before they enter the cotton fields.

Seasonal incidence of diapause in the boll weevil in Lower Rio Grande Valley of Texas was studied at Brownsville. Boll weevils were collected through the year from cultuvated or regrowth cotton. The peak percentage

of weevils in diapause occurred in late September in males (34%) and in October in females (30%). The percentages then dropped sharply and peaked again in late December.

In a replicated study of boll weevil hibernation environments and weevil movement during the hibernation period at Florence, S. C., the following treatments were included: 1-,2-,3-, and 4-inch depths of woods trash receiving (1) no rainfall, (2) normal rainfall and (3) 3-times normal rainfall. The highest survival occurred in the no rainfall and normal rainfall treatments. The greatest weevil movement was from the 3-times normal rainfall treatment with about equal numbers of the weevils moving to the 2 other treatments. The greatest amount of movement from the no rainfall treatment was to the normal rainfall treatment.

In studies at Waco, Texas, twenty one weevils were collected on 12 3 x 5 ft flight screens spaced 68 ft apart along the edge of a field planted to cotton in the previous year and bordered by a wooded area that was about 15 ft. deep. The first weevil was collected on April 10 and the last on June 19. Fourteen were collected in April, 4 in May, and 3 in June.

Fall woods trash examinations indicated a hibernating population of 4,877 weevils per acre in Falls, Hill, Limestone, and McLennan counties, Texas, in 1966. More boll weevils entered hibernation quarters in the fall of 1966 than in any year since 1959. Spring examinations in 1967 indicated a population of 1,292 per acre for a survival percentage of 26.5. Field inspections in early summer indicated heavy overwintered boll weevil infestations over the area.

In March, 1957, a colony of boll weevils was started at College Station, Texas with adults obtained at Manuel, Tamaulipas, Mexico. The colony has been maintained in the laboratories for the past ten years without the introduction of any new stock. In the entomology laboratory the larvae are now being reared in petri dishes on a cottonseed meal diet and the adults are given cotton seedlings and cotton bolls for food and oviposition. In the biochemistry laboratory larvae are reared aseptically on a standard casein diet containing corn and linseed oils. Adults are fed a germinated cottonseed diet. Between 140 and 150 generations of boll weevils have been reared during the ten-year period.

A technique was developed at State College, Miss. for measuring food consumption of the adult boll weevil with a red dye. Quantitative recoveries of the dye were made 0-, 2-, 4-, and 9-hours post-injection from live weevils. The red dye gave results nearly identical to the more cumbersome and expensive chromic oxide method.

A dye applied in a bait with a ground machine marked field populations of boll weevils at Tallulah, La. Marked weevils were also recovered from

ground trash collected near the cotton field. Trash examinations made 12 and 33 days following the last dye application indicated that 44 percent of the hibernating weevils were marked. In a sample collected in early March, 38% showed visible external markings, but 72% showed markings when the weevils were dissected.

Field populations of boll weevils were marked with cottonseed oil-Calco Oil Red N-1700 dye bait formulations in two field experiments in Mississippi. In a field experiment conducted in Carroll County, Mississippi, 57% of the overwintered weevil population was visibly marked red in the abdominal fat body. In a second experiment conducted in Oktibbeha County, Mississippi, during October, the maximum percentage of the field population marked was 51%.

The third year of an insecticidal control program aimed at reducing the diapausing boll weevil population in an eight county area of the High and Rolling Plains of Texas was completed November 4, 1966. The potential overwintering population in the control zone in 1966 was estimated to be 96.7% less than in nearby untreated acreages. Examinations of leaf litter in locations known to be suitable for boll weevil hibernation indicated that the 1966-1967 overwintering population in the treated zones was extremely small. Records indicated that the potential overwintering population in February, 1967 was 42% smaller than in February, 1966. Only one boll weevil was found on cotton in the Control Zone in June, 1967.

In eighteen 200 ft plots of cotton planted near favorable quarters for boll weevil hibernation in the Brazos River Bottom near College Station, Texas, boll weevils infested the plots through June with the largest numbers appearing after plants began to square. Two weevils were found during the first 6 days of July and none thereafter. The results were from the first year of a three-year study.

The region of the light spectrum with the greatest influence in preventing diapause in the boll weevil was between 485-570 mμ in studies at the Boll Weevil Research Laboratory. Less sensitive regions of the light spectrum were 350-390 mμ and 670-1000 mμ. One group of immature weevils was exposed to an 11-hour fluorescent light period which initiates diapause in this insect; a second group to a 13-hour fluorescent light period which inhibits diapause; and a third group to an 11-hour fluorescent period followed by 2 hours of illumination with narrow bands of light of different spectral composition. Suppression of diapause with the 2-hour extension of the 11-hour fluorescent light period implies sensitivity. Induction of diapause comparable to an 11-hour fluorescent light period implies insensitivity to a given narrow band of light of known spectral composition.

Sucrose rich larval diets affected the titer of trehalose, sugars other than trehalose, and total lipids in larvae, prepupae, and newly emerged

boll weevil adults in studies at Baton Rouge, La. When larvae were fed a diet containing 10 times the normal concentration of sucrose, late last instar larvae and prepupae contained about 1.6 times as much trehalose as insects of the same age reared on the usual amount of sucrose. In the newly emerged adults, however, trehalose levels were about the same regardless of whether the larvae were fed the high or low sucrose diets. Late last instar larvae reared on the sugar rich diet contained a very large amount of sugars other than trehalose; but the titer of these sugars dropped abruptly in the prepupa. The decrease coincided with a slight increase in total lipids and suggests that part of these sugars may be converted to lipids at this time. Trehalose may not be a precursor of lipids since trehalose levels were about equal in the late instar larvae and prepupae. Although the larvae, prepupae, and adults reared on the sucrose rich diet contained 2 to 3 times as much total lipid as those reared on the normal sucrose diet, there was little difference in the quantity of lipid metabolized during the pupal period by weevils fed either the normal or the sucrose rich larval diet, indicating that the same quantity of lipid is metabolized during the pupal stage regardless of the amount of the lipid reserves.

In studies at College Station, Texas, uptake of UC-21149 by cotton plants was influenced by its concentration. Uptake by cotton plants growing in nutrient solution was not reduced by low concentration of UC-21149, but concentrations of 10 ppm or more reduced uptake.

In studies at Florence, S. C., results of preliminary dry film laboratory tests indicated differences in free fatty acids between boll weevils that are sensitive and insensitive to toxaphene. The data indicated that there are more free fatty acids and an unidentified compound in boll weevils that were affected by exposure to a dry film of toxaphene than in those that were not affected by the insecticide.

Lipids from thurberia weevils and from several boll weevil complex populations from Arizona were similar in studies at Baton Rouge. The relative amounts of fatty acids, sterols, and polar steroids were determined by gas- and thin-layer chromatography. It was concluded that the analysis of these biochemicals would be of little value in determining whether a certain population of weevils was more closely related to the thurberia weevil or to the boll weevil.

In studies at College Station, Texas, canavanine, an analogue of arginine, in the diet was toxic to developing boll weevils. The toxicity was partially overcome by increased amounts of arginine and homoarginine.

In studies at Baton Rouge, La., aza sterols limit the boll weevil's ability to convert β-sitosterol to cholesterol. Boll weevils fed two aza sterols in addition to β-sitosterol were analyzed by gas chromatography. An intermediate product, believed to be desmosterol, appeared in

increasing amounts as the level of aza sterol in the diet increased.

In studies at the Boll Weevil Research Laboratory, eight nucleotides and nucleosides were found in newly laid boll weevil eggs. Adenosine, guanosine, and inosine were tentatively identified. Other guanine and hypoxanthine type compounds were present.

Results of feeding and injection experiments at Baton Rouge, La. indicated that the poor utilization of galactose by the boll weevil is due to the slow rate of absorption of this sugar through the gut wall. Galactose fed weevils contained a large amount of total anthrone positive substances, but trehalose, while synthesized from galactose, accounted for only a small portion of these sugars. This indicates that a large amount of unmetabolized galactose is present in the boll weevil. Most of the galactose probably is present unabsorbed in the gut since galactose is quickly metabolized when injected into the hemocoele.

Trehalose from several thousand Phormia regina adults has been purified at the Baton Rouge, La. laboratory. This enzyme will be used to increase the accuracy and sensitivity of trehalose determinations in studies of other insects.

Several hundred grams of chitin have been isolated from shrimp shells and squid cuttlebones at the Baton Rouge, La. laboratory. The chitin will be used in performing quantitative analyses for chitin in the boll weevil.

Addition of the pyrethrum synergist, Sesamex, to the diet of the boll weevil slightly inhibited the formation of two steroid metabolites in studies at Baton Rouge. Egg production was also reduced, but it is not known whether the loss of fecundity was related to impaired steriod production or to other unknown metabolic changes.

Triethylene and propylene glycols vaporized in several rearing rooms reduced the airborne contamination as much as 98% in some cases in studies at the Boll Weevil Research Laboratory. The number of contaminants was very often reduced to less than 1 per open petri dish per hour of exposure. The glycols were not able to maintain this effect when large amounts of contamination were consistently introduced into the air, emphasizing the need for continually practicing sanitation along with glycol vaporization. No adverse effects on the boll weevils or the two protozoan pathogens were observed in limited tests.

2. Bollworms. No synthesis of fatty acid from labeled acetate in a complete incubation medium took place in the mitochondria of whole bollworm homogenates in studies at Baton Rouge, La. The enzymes responsible for lipid synthesis in Heliothis zea are very labile, and rapid loss of activity occurs during fractionation with ammonium sulfate. No synthesis of unsaturated fatty acids was observed either in whole homogenates or in

various cytoplasmic fractions. There was no radioactivity incorporated into the nonsaponifiable matter, indicating a complete lack of hydrocarbon and sterol biosynthesis in the in vitro system in this insect.

In studies at Baton Rouge, trehalose was present in Heliothis virescens adults. This is the first time that this sugar has been reported in a moth. Although levels varied considerably between individuals, the titer of trehalose rose the first two days and then tended to level off. After 7 days sugars other than trehalose appeared in detectable quantities.

The tobacco budworm was found only on cotton in central Texas in the fall of 1966. Heliothis zea (Boddie) larvae were collected on 6 of 20 different host plants (tomatoes, wild morning glory, fall corn, second crop maize, alfalfa and cotton) inspected in Falls and McLennan Counties. Heliothis virescens (F.) larvae were collected on cotton only.

Heliothis spp. eggs were collected from 5 different host plants during March, 1967 at Waco, Texas. One larvae and 84 eggs were found on 185 Texas Star plants, 14 eggs on 370 Indian paintbrush plants, 1 egg on 300 alfalfa plants, 1 egg on 450 wild verbena plants,and 1 egg on 750 bluebonnet plants in inspections of early-season host plants for Heliothis spp. activity.

The addition of polyethylene pellets to the wheat germ diet for rearing Heliothis spp. larvae significantly increased growth rates and shortened developmental time in the laboratory at Brownsville, Texas. The pellets apparently changed the physical properties of the diet.

First-instar H. zea and H. virescens gave a greater phototactic response than any other instar or than the prepupa in studies at Brownsville. Sixth-instar larvae and prepupa were the most photonegative. All larvae showed the greatest negative response to red light.

During June to August, 1966, H. virescens was the predominant Heliothis spp. in the lower Rio Grande Valley of Texas. Parasitism of eggs of Heliothis species by Trichogramma semifumatum in a field treated with insecticide reached 36% after insecticidal treatments were discontinued. Parasitism of larvae by a complex of parasites in the same field reached 25%.

Honeycomb-like trays were efficient in rearing tobacco budworms in the laboratory at Brownsville. A rectangular tray containing a honey-comb-like polyester film to separate larvae developing on artificial medium used to rear tobacco budworms saved labor and materials compared with the plastic cup method. The honeycomb cells were infested with eggs instead of newly hatched larvae used in the cup method. A record of pupae from sample honeycomb trays showed an average yield of 0.7 pupa per cell.

A high percentage of larvae collected on cotton in June, 1967 in Central

Texas near Waco were H. virescens. Of 411 larvae collected on cotton in June, 263, or 64% were H. virescens (F). Of 26 larvae collected in May, all were determined as H. zea (Boddie).

In the bollworm diet used in the laboratory at Brownsville, ethanol at a percentage of 1.35 is normally present. Ethanol in the tobacco budworm diet increased larval mortality and decreased development time.

The flowers of 41 lines of cotton were chromatographed for flavonoid content at Brownsville. There were some qualititative differences between lines. However, the most significant difference in flavonoid content between lines appeared to be the relative concentration of each of the flavonoid compounds.

In field studies in Brownsville, peak parasitism of Heliothis spp. eggs by Trichogramma semifumatum followed peaks in host oviposition. Releases of 14,400 to 81,480 parasites twice weekly in a 3 acre field resulted in parasitism of 41.2% and 37.5% of Heliothis spp. eggs. Parasitism declined to low levels when host populations were low.

Bollworm pupae attain diapause in large numbers in the Mississippi Delta area about September 15. Grown larvae were caged on the soil at weekly intervals beginning in July. By September 13, over 30% of the larvae had emerged as moths. There was no moth emergence from larvae installed in cages from September 26 to October 21.

Developmental time for Lespesia archippivora (Riley) on bollworm larvae ranged from 46.7 days at 59° F. to 13.8 days at 95° F. at Tucson, Arizona. The greatest number of pupae were obtained at a rearing temperature of 77° Poorest survival of pupae was at 95° F.

Results of electrophysiological tests at Florence, S. C. indicated that bollworm moth ear preparation detected pulsed ultrasound from as far away as 250 feet. Bollworm moth acoustic sense cells responded to pulsed 20 KHz ultrasound from a modified ultrasound speaker (108db at 1 meter) 250 feet from the moth. The speaker is very directional and the sound level drops off rapidly at angles greater than 10 degrees from a perpendicular line through the center of the speaker.

Under caged conditions at Stoneville, Miss. the bollworm, Heliothis zea, maintained itself on cotton from July 13 until the plants were killed by a freeze on November 3. At least 3 generations of larvae fed only on cotton plants without any apparent loss in vigor. The soil in the cages was full of living pupae at the end of the season.

In studies at Stoneville heavy infestations of bollworms (Heliothis zea) reduced the yield of cotton as much as 95%. Initial larval infestations of 1,2,3, and 4 larvae per hill of 4 plants at the time plants were

producing squares one-half grown, were allowed to build for the remainder of the growing season. The above infestation rates resulted in yield reductions of 1762, 2256, 2610, and 2720 pounds of seed cotton per acre, respectively.

3. Pink Bollworm. In studies at Phoenix, Ariz., a high percentage of pink bollworms diapaused by October 1. From 0 to 7 percent of pink bollworm larvae from bolls attained diapause by mid-September at various locations. By October, 55 to 90 percent of the larvae attained diapause.

In studies at Brownsville, Texas, first-instar pink bollworm larvae exhibited a positive phototaxis to radiation ranging from near ultraviolet through the visible spectrum. They were repelled by infrared radiation. When the larvae were irradiated with several passbands simultaneously, they always responded to the passband with the shortest wavelength.

Pink bollworm collections in sex lure traps on St. Croix, Virgin Islands made by Tobacco Insects Investigations personnel cooperating with the Brownsville, Texas, laboratory showed sharp increases in early February. Collections had been low since May, 1966. The increase appeared related to lack of attractive breeding sites.

Three flavonoid compounds (isoquercitrin, quercitrin, and rutin) included in the diet increased the development time to pupation and decreased pupal weight in laboratory tests with pink bollworm at Brownsville, Texas. Gossypol, also, adversely affected the development of pink bollworms.

4. Other Insects. At Stoneville, Miss., heavy plant bug infestations reduced the yield of cotton as much as one bale per acre in cage tests. Five weekly releases of tarnished plant bug adults at the average rate of 1.6 per plant on caged cotton plants at squaring gave a reduction of 1305 pounds of seed cotton per acre. Lighter or later infestations gave smaller reductions.

In studies at Stoneville only 40% of tarnished plant bug females laid fertile eggs. This low degree of fertility makes it very difficult to produce plant bugs in significant numbers in the laboratory.

Field observations at Tucson, Ariz. indicated that diapause in Lygus bugs may start in August and the entire population attains diapause by October 1. Egg laying begins again in early December. Diapause may be broken in the laboratory in increasing the length of the light-day.

In studies at Tucson, the nymphal developmental period of Lygus hesperus averaged 13 days at 86° F and 28 days at 68° F. There was little difference in the duration of the developmental period between sexes. The development period for the fifth instar was longest, and shortest for the second instar. Developmental periods have been determined to aid the

grower in predicting Lygus damage.

In studies at Tucson sugars enabled Lygus spp. nymphs to survive on non-flowering alfalfa. Melezitose (the main trisaccharide present in honeydew), sucrose, and honey markedly increased survival of lygus bug nymphs confined on alfalfa plants. Nymphs have a hard time surviving on non-flowering plants. Field plots sprayed in 17% sucrose and honey solutions were highly attractive to adults.

A unisexual strain of salt-marsh caterpillar (Estigmene acrea (Drury) was maintained in the laboratory for 4 generations at Baton Rouge, La. The culture originated from a field-collected egg mass that yielded 105 females and no males. When females were mated with males from a bisexual culture a total of 422 additional females and only 2 males were produced during the next 3 generations. By contrast, a laboratory maintained bisexual culture yielded 242 females and 218 males during the same period. The average egg hatch for both cultures was less than 50%. However, hatch of eggs from some females of the bisexual strain sometimes exceeded 50%, but this never occurred in the unisexual strain. Unmated females from the unisexual strain laid infertile eggs, and females mated with y-irridiated males produced very few viable eggs. This tends to rule out gynogenesis as a cause of the biased sex ratio. It is believed that essentially all of the males in the unisexual strain die during the embryonic stage. Thus far we have been unable to infect females from the bisexual strain with a "male lethal factor" from the unisexual strain. Virgin females from both cultures were found to be attractive to males when tested in the field.

The sex-ratio factor in Estigmene acrea was transferred from the unisexual to a bisexual strain by an injection of pupal hemolymph at Baton Rouge, La. These results indicate that the unisexual strain carries an infective agent that penetrates the developing eggs resulting in the death of male embryos.

Optimum rearing temperature for the salt-marsh caterpillar, Estigmene acrea (Drury), were 77° F and 86° F in studies at Tucson, Ariz. At 77° F the hatch of eggs was greatest and the preoviposition and oviposition periods shortest. At 86° F the developmental period was shortest for all stages of the insect. Above 86° F developmental times increased and at 95° F no insects were reared to adults.

The effect of ethanol on Heliothis and other lepidopterous species was compared in studies at Brownsville, Texas. Ethanol incorporated into the media at levels of 1.25, 1.9, and 2.6%, resulted in mortalities of 8.3, 19.4, and 97.2%, respectively, of cabbage looper larvae up to 9 days old. The 1.35% level is the amount normally present in the bollworm diet.

In studies at Tucson, Ariz. developmental time for Lespesia archippivora (Riley) on cabbage looper larvae varied from an average of 44.9 days at 50° to 11.3 days at 95° F.

Metabolism studies at College Station, Texas with P^{32} trichlorfon indicated that the tolerance of Chrysopa carnea larvae to this toxicant is due to slow penetration and slow conversion of trichlorfon to DDVP (presumably the actual toxicant). Trichlorfon and DDVP are very rapidly detoxified by tobacco budworm larvae and cotton leaves.

Six generations of Chrysopa carnea were reared in the laboratory at College Station. The technique used in the rearing procedure was a modification of that employed by Vitona Company, Inc., Rialto, California, for producing the insect commercially.

Position and movement of third instar Chrysopa larva released on cotton plants was studied at College Station. The larvae moved an average of 28.8 inches in 72 hours. Most of them were found inside the bracts of squares and on the underside of leaves. Seventy one percent of the larvae were recovered in the top half of the plant.

The developmental time of Chrysopa larvae was influenced by food in studies at College Station. Chrysopa larvae fed bollworm eggs, aphids, or Sitotroga eggs require about 8 days to complete larval development from first instar until the time spinning begins in late third instar. When they were fed bollworm larvae or mites, their development times was somewhat longer. Third instar larvae consumed 7 to 8 times more food than first instar larva. First instar larvae preferred aphids to all other prey offered; second instar larvae fed about equally on aphids, Heliothis eggs and Heliothis larvae; and third instars preferred Heliothis larvae.

Ease of collecting adult Nabids in the field, their longevity, oviposition, and the small number of dissected females without mature eggs and with excessive fat during the winter, in studies at Tucson, Arizona indicated that Nabids overwinter mainly in the adult stage in southern Arizona. However, at the winter temperature of 1966-67 the Nabids apparently were active in the field during the entire winter. Mating, ovipositing, feeding, and hatching must have occurred because nymphs of all ages were collected.

In studies at Tucson, Ariz., Nabis alternatus and N. americoferus readily attacked cabbage looper and beet armyworm larvae in preliminary field cage tests. Geocoris punctipes showed little effectiveness as a predator of beet armyworms. Hippodamia convergens was ineffective against beet armyworm and salt-marsh caterpillar larvae. G. punctipes and N. alternatus readily preyed on Lygus hesperus when proper pairings of host and prey were made.

Nabis alternatus females collected in March laid an average of 21 eggs in the laboratory at Tucson. Seventy five percent of the egss hatched, the majority in the seventh day after oviposition at 79° F. The average

Oviposition period was 3.4 days for 43 of 50 females that oviposited. The females lived an average of 7.8 days after capture and the companion males 8.2 days.

In studies at Tucson the developmental period for Lespesia archippivora (Riley) in the salt-marsh caterpillar ranged from an average of 57 days at 50° to 14 days at 86° F. The average developmental periods in the salt-marsh caterpillar host is similar to that in the beet armyworm, bollworm, and cabbage looper. Parasite mortality was markedly increased at a rearing temperature of 95° F.

Tachinid parasites were reared from field-collected Nabis spp. and Lygus spp. in the laboratory at Tucson. Hyalomya aldrichii Ins. was reared from Nabis alternatus Parshley, N. americoferus Carayon and Lygus spp. Leucostoma simplex (Fall.) was reared from N. alternatus, and Leucostoma sp. and Alophorella sp. were reared from Lygus spp. Efforts to propagate the parasites were not successful.

Cold treatment influenced sex ratio of Campoletis perdistinctus Viereck in studies at Brownsville, Texas. When newly mated females of C. perdistinctus infested host larvae, the sex ratio in the F_1 progeny was 1:5.4 (♀ : ♂). When females were mated and then held at 56° F for 1,2,3,4,5, and 6 days before infesting the host, the sex ratio (♀ : ♂) of the F_1 progeny was 1:1.7, 1:1.6, 1:1.4, 1:2.4, 1:1.3, and 1:1.6, respectively.

B. Insecticidal and Cultural Control

1. Boll Weevil. In field plots at Waco, Texas, in 1966, Union Carbide-UC 21149 applied at 1 lb/acre as a granular sidedressing at first squaring of the cotton plants controlled overwintered boll weevils as effectively as 2 foliage sprays of azinphosmethyl at 0.25 lb/acre. Side dressings of UC-21149 granules applied to cotton reduced overwintered boll weevil populations in 2 of 3 tests in 1967. In one experiment sidedress applications of UC-21149 reduced overwintered boll weevil populations 50% at 1.1 and 2.2 lb/acre and 90% at 4.1 lb/acre. Two applications of azinphosmethyl at 0.25 lb/acre reduced populations 100%. In another test UC-21149 at 1.0 and 2.1 lb/acre gave reductions of a heavy overwintered boll weevil population comparable with that obtained with 2 applications of malathion at 1.1 lb and azinphosmethyl at 0.25 lb applied in ultra-low volume spray. In a third test, sidedressings of UC-21149 at 1.2 and 2.9 lb/acre gave no control of overwintered boll weevils on early planted squaring cotton growing in a heavy clay soil.

At Waco kill of overwintered boll weevils caged on plants that had been sidedressed with UC-21149 was good. Seven days after cotton was sidedressed and weevils were caged on plants, kill on plants treated at 1.1 lb/acre was 80%, on those treated at 2.2 and 4.1 lb/acre, 100%. Kill was 90% on plants treated at 0.25 lb/acre of azinphosmethyl applied as a spray.

In cage tests at College Station, kill of boll weevils by sidedressings of UC-21149 to cotton plants was enhanced when the plants were sprayed with a cotton seed oil feeding stimulant. This indicated that the stimulant induced boll weevil feeding on plant foliage in the presence of squares on the plant.

In laboratory tests at College Station, Decagin was promising as a thickening agent in formulations of materials for stem treatments. Union Carbide UC-21149, American Cyanamid CL-47031 and General Chemical GC-6506 were effective against the boll weevil when applied as seed treatments in formulations with Decagin.

Granular UC-21149 applied at planting and again before cotton plants began to square was effective against overwintered boll weevils and the cotton aphid but ineffective against the bollworm at Florence, S. C. In small plot field tests in which weevils were caged on treated plants, one pound of UC-21149 per acre applied at planting (May 3) was highly effective for up to 40 days in reducing the numbers of overwintered boll weevils in the treated plots. Side dress applications at the 8-leaf stage (June 18) of 1.2 and 4 lb/acre gave boll weevil mortality for increasing lengths of time up to 16 days after the sidedressing. There appeared to be a positive correlation between rate of application and number of bollworm-injured squares.

Field tests at Florence indicated no differences in effectiveness of materials against boll weevils, applied conventionally or in ultra low-volume. In replicated small plot field tests there was no significant difference in boll weevil control or cotton yield in the plots treated with azinphosmethyl at 0.25 lb, methyl parathion at 0.375 lb, or malathion at 1.25 lb, applied conventionally or ultra low volume. In replicated small plot field tests,toxaphene at 2 lb, plus DDT at 1 lb plus methyl parathion at 0.5 lb/acre and methyl parathion at 1.0 lb/acre applied conventionally and in ultra low-volume gave equal control of the boll weevil but the ULV application of methyl parathion gave better control of the bollworm than the conventional application. There was no difference in yield among treatments .

Results of studies by personnel of the Tucson, Ariz. laboratory showed that boll weevil populations were light in the boll weevil eradication area of Presidio, Texas and Ojinaga, Chihuahua, Mexico. The 1965 fall diapause program substantially reduced 1966 populations and heavy infestations occurred in only localized areas in 1966. Large populations of bollworms built up during the 1966 fall spray program with ultra-low volume applications of malathion.

At State College, Miss., ultra-low volume applications of azinphosmethyl at 0.25 pound and of malathion at 0.5 pound per acre gave good control of the boll weevil during the cotton growing season and of diapausing populations in the fall. Azinphosmethyl at 0.125 pound per acre gave satisfactory

control but conditions were ideal for insecticide applications during the course of the experiment.

At Tallulah, ultra-low volume applications of 0.5 pound malathion plus 0.5 pound of endosulfan, 0.5 pound of malathion plus 1.0 pound of DDT, 1.2 pound of malathion, 0.25 pound of azinphosmethyl plus 1.0 pound of DDT,and 2 pounds of toxaphene plus 1.0 pound of DDT per acre gave boll weevil control comparable to that of 2 pounds of toxaphene plus 1.0 pound of DDT per acre in a conventional spray.

At Stoneville, Miss. there was no difference in boll weevil control obtained with 0.25 pound of azinphosmethyl applied in ultra-low volume spray with a mist blower or spinning disc machine and in a conventional spray. Results against the boll weevil obtained with 2 pounds of toxaphene plus 1.0 pound of DDT per acre applied in an ultra-low volume spray with a mist blower or spinning disc sprayer and conventional spray were similar.

2. Bollworms. At Stoneville, Miss. there was no difference in bollworm control obtained with 0.5 pound of malathion plus 1.0 pound of DDT, or with 2 pounds of toxaphene plus 1 pound of DDT per acre applied in ultra-low volume sprays with a mist blower or a spinning disc sprayer. Results compared favorably with 2 pounds of toxaphene plus 1.0 pound of DDT per acre applied in a conventional spray.

At Brownsville, Texas, ultra-low volume sprays of methyl parathion at 1.0 to 1.5 pounds,EPN at 1.0 pound, and 0.75 pound of Azodrin plus 0.75 pound of Strobane per acre gave good control of a mixed population of bollworms and tobacco budworms.

At Florence, S. C., conventional sprays of EPN at 0.5 pound, 0.5 pound of EPN plus 1.0 pound of DDT, 1.0 pound of Niagara NIA-10242, 0.6 pound of Azodrin, 1.0 pound of Monsanto CP-47114, 1.0 pound of methyl parathion, and 2 pounds of toxaphene plus 1.0 pound of DDT per acre gave good control of bollworms.

Union Carbide UC-34096 and Velsicol VES-506 gave 80% or better mortality of bollworm and tobacco budworm larvae at 1 lb/acre in laboratory tests at Brownsville, Texas. EPN, methyl parathion and CP-47114 gave greater mortality when applied in ultra-low volume sprays than in emulsion sprays.

Decagin was promising as a thickening agent in formulations of materials for stem treatments in laboratory tests at College Station, Texas. Lannate, General Chemicals GC-6506 and Azodrin were effective against bollworms when applied as stem treatments in formulations with Decagin.

3. Other Insects. Azodrin at 0.5 lb/acre applied as a stem treatment gave season long cotton fleahopper control in field tests at Waco, Texas. One application of Azodrin at 0.5 lb/acre applied as a stem treatment gave good control of a heavy cotton fleahopper infestation for approximately

3 weeks and gave significantly better control than 2 applications of toxaphene at 1.5 lb plus DDT at 0.75 lb/acre.

Thrips control with UC-21149 granules in the seed-furrow was effective in field tests at Tallulah, La. and increased the height of plants and the numbers of squares, blooms, and bolls. At Stoneville, Miss., UC-21149 granules applied in the furrow at planting time gave increases in yield up to 1250 pounds of seed cotton per acre.

In a field test at Waco, Texas, Hercules 13462 at 0.9 pound/acre, disulfoton at 1.2 pound and UC-21149 at 0.3, 0.6, and 1.2 pound/acre reduced the thrips infestation significantly below that of the check. The 0.6 and 1.2 pound/acre rates of UC-21149 were better than Hercules 13462. In field tests at Stoneville, Miss., UC-21149, NIA 10242, GS-6506, disulfoton, and phorate gave protection to cotton plants from thrips, when applied as granules in the furrow with the cottonseed, as treatments on the cottonseed, or as sprays in the furrow with the cottonseed at planting. In general, granule treatments gave longer plant protection than treatments applied directly to the seed. UC-21149 applied in the seed furrow at planting gave good thrips control at Florence, S. C.

Granular formulations of UC-21149 and NIA 10242 applied in the furrow at planting gave up to 14 weeks control of tarnished plant bugs in field cage tests at Stoneville, Miss.

The predominant spider mite species in cotton fields in the Delta of Mississippi according to personnel of the Stoneville laboratory was the two spotted mite T. urticae. In a survey in August, 79 percent of the cotton fields infested with spider mites were infested with this species. Dicofol, chlorobenzilate, Chloropropylate and tetradifon were effective against the two spotted mite in field tests. Laboratory tests showed Chloropropylate, dicofol, tetradifon, Azodrin, and Thiocron to have ovicidal properties.

C. Biological Control

1. Boll Weevil. Effectiveness of the microsporidian and Mattesia grandis, the two boll weevil pathogens, in a bait formulation was compared in 1/16 cage tests at the Boll Weevil Research Laboratory. The microsporidian did not suppress the numbers of adult boll weevil as much as M. grandis, but cotton yields were the same. Both diseases suppressed weevil populations by about 50% compared with the uncontrolled caged populations. Neither disease controlled the population well enough to compete with insecticidal control. The average yield from the 4 cages where the pathogens were used ranged from 0.3 to 0.4 bale/acre. The tests were severely handicapped by a long rainy period during the important time of F_1 emergence and peak egg production, preventing any bait from remaining on the plants for over 1 to 2 days. Under better weather conditions, the pathogens would probably have had greater effect. The results do indicate that the bait

principle can introduce disease agents into a population and that these pathogens can influence the population.

The microsporidian disease was not transmitted by infected males to females during mating and the progeny was not infected in studies at the Boll Weevil Research Laboratory. The disease does not attack the testes until in the late stages of the infection. When spores were detected in the sperm bundles males were usually too weak to mate or did so reluctantly. Because of this, the likelihood of transmission of the disease by the males is probably very small. The reluctance to mate could be an advantage, because such males would lower the reproductive potential of a population. If a large percentage of the males were infected, the total effect on reproduction could be important.

Female boll weevils infected with the microsporidian laid fewer eggs per day and did not live as long as healthy females in studies at the Boll Weevil Research Laboratory. The rate of oviposition was only 33.2% that of healthy females. In addition, 45% of all progeny from infected females were infected. Infected progeny do not develop into effective individuals. The overall effect of the disease on reproductive potential was a reduction of 82%.

In studies at the Boll Weevil Research Laboratory, Bracon kirkpatricki from Africa was an effective parasite of the boll weevil in a 1-acre cotton field. Between June 16 and September 6, 47,300 adults were released in a joint control program with flail machine destruction of infested fallen squares. Boll weevil populations were held at low levels through midseason. Percentages of parasitism ranged from 11 to 81 in hanging squares and from 17 to 76 in fallen squares. B. kirkpatricki represented 93% of all weevil parasites that emerged.

Personnel of the Boll Weevil Research Laboratory found no evidence of survival of Bracon kirkpatricki over the winter after a full season of releases in a Mississippi field. Storage of 1500 Bracon mellitor cocoons containing diapausing prepupae at 35° - 40° F produced 22% adults after 1 year. Results indicated the possibility of stockpiling these parasites for field release. A new technique for surveying for boll weevil parasites involving exposure of artificially infested squares resulted in 21% parasitism by 4 native parasite species.

A colony of the little-known boll weevil parasite, Heterolaccus grandis was established at the Boll Weevil Research Laboratory. Its aggressive attack of boll weevil larva, short life cycle, satisfactory longevity and fecundity all recommend it for testing for control of the boll weevil.

2. Bollworm. Surfactants improved the Heliothis nuclear polyhedrosis virus residues on cotton leaves in studies at Brownsville, Texas. Virus could be detected up to 9 days after leaves were painted with a suspension of 10^9 polyhedral inclusion bodies/ml of a nuclear polyhedrosis virus.

However, there was a rapid loss or inactivation of virus in the field within 3 days. The addition of surface active compounds prevented some of this loss. Conservative estimates indicated a 97 percent loss of virus activity in 3 days when virus water suspension was used alone. When a surfactant (e.g. amine S) was added to the suspension there was only a 11 percent loss of virus activity in 3 days.

At Florence, S.C., Bioferm Heliothis virus applied at rates of 10, 50, 100 diseased larval equivalents/acre, Nutrilite VHE virus applied at 10, 25, and 100 diseased larval equivalents/acre, and Stauffer Thuricide 90TS applied at 2 quarts/acre were ineffective against bollworm spp. in replicated small plot field tests in 1966.

Extenders of the Heliothis nuclear polyhedrosis virus were evaluated in the laboratory at Brownsville. A major problem in the use of the Heliothis virus in the field has been its poor persistence. A paraffinic oil, a paraffinic oil with ultraviolet screen, Dacagin, a resin, and cottonseed oil were tested as virus extenders. The resin increased the persistence of the virus and in preliminary tests, cottonseed oil showed promise as an extender for virus effectiveness.

The compatability of azinphosmethyl and Heliothis virus was determined in studies at Brownsville. Heliothis virus activity was decreased after being mixed with azinphosmethyl for 24 hours at 80° F.

Aging of nuclear polyhedrosis virus preparations influenced nuclear and cytoplasmic virus interaction in studies at Brownsville. Tests from a single source and preparations of cytoplasmic virus in combination with nuclear polyhedrosis virus against Heliothis virescens indicated no interaction. Aging of virus preparations at 4° C apparently affected interaction since results of replicates examined individually indicated synergism (first replicate) antagonism (second replicate) or no interaction (third replicate).

Interaction of cytoplasmic and nuclear polyhedrosis viruses was observed in bollworm populations at Brownsville. Single preparations of cytoplasmic and nuclear polyhedrosis viruses were assayed individually and mixed in various ratios. Mortality in H. zea with mixed virus was greater than with either virus alone indicating a definite synergistic effect.

The Heliothis spp. nuclear polyhedrosis virus gave poor control of bollworms in field tests at Stoneville, Miss., Tallulah, La., and Waco, Texas.

Results of studies under contract by the Entomology Department, Texas Agricultural Experiment Station, Texas A&M University indicated that several common adjuvants could be used in the liquid spray without reducing effectiveness of the virus. The virus could be mixed with carbaryl, toxaphene plus DDT, and methyl parathion without reducing its effectivenss. Feeding stimulants used with the virus increased feeding of bollworms and mortality caused by the pathogen. Ultra-violet light reduced effectiveness of the

virus against tobacco budworm.

In studies under contract with the Entomology Department, Mississippi Agricultural Experiment Station, the comparative effect of ultra-low volume applications of malathion and conventional applications of toxaphene plus DDT plus methyl parathion applied for bollworm and boll weevil control on beneficial insects was determined. Both materials affected predator populations adversely although the ultra-low volume malathion affected them less severely than toxaphene plus DDT plus methyl parathion. However, it was concluded that after the first two treatments of ultra-low volume malathion, the predator population played only a small role in controlling the bollworm infestation.

Results of a study conducted under a grant by the Entomology Department, University of California, Davis, indicated that the araneid fauna is distinctive at each of the three major sample locations in the San Joaquin Valley cotton fields with some species common to all locations. To date, 24 species representing 14 families were identified. The most common species at all locations during the past growing season were: Misumenops deserti, Pardosa sternalis, Erigone dentosa, Theridiidae spp., I. and Dictynia reticulata. In addition Xysticus californicus was extremely abundant at one location and Neascoma spp. was very abundant at one location only, during the latter part of the season. The faunal composition was highly variable from year to year with some species present in 1965 being absent in 1966, while new species appeared to replace them. For example, the black widow spider, Latrodectus mactans was absent in 1965 and extremely abundant in 1966.

In a study conducted under a grant by the Entomology Department, Arkansas Agricultural Experiment Station, University of Arkansas, a media based on whole egg was developed and Coleomegilla maculata was reared on it for five generations. The Heliothis spp. egg consumption of the various instars of C. maculata in 24 hours at 80° F was as follows: First, 7.7; second, 24.1; third, 47.5, and fourth 94. Effect of age of adults on numbers of bollworm eggs consumed at 80° F was as follows: First 10 days, 127, second 10 days 169; and third 10 days, 154. The effect of larval food on the number of bollworm eggs consumed by the resultant adults were as follows: Reared on aphids, 149; reared on bollworm eggs, 149; and reared on media, 127.

3. Other Insects. Results of studies at Tucson, Ariz., on the longevity, fecundity, and parasitic efficiency of Leschenaultia adusta (Loew) indicated it has potential as a biological control agent. At 80° F adult females have a life span of 11 days with 3.9 days in the preoviposition period. The average number of eggs laid per female was 876. Four, 6, or 10 eggs fed to a single salt-marsh caterpillar larvae produced the greatest percentages of parasitism.

Exorista mella showed promise as a lepidopterous larval parasite in field cage tests at Tucson. In field cage studies as many as 269,063 salt-marsh caterpillar larvae could be parasitized by Exorista mella over a life span of 21.9 days if the parasite density of 1.0 female/9 ft^2 was imposed on a host density of 1.0 larvae/0.8 ft^2.

In a field experiment at Waco, Texas, populations of Heliothis spp. predators and parasites were reduced on plants sidedressed with Temik. There were significantly more predators and parasites in plots treated with azinphosmethyl and malathion and in the untreated check than in plots that were sidedressed with UC-21149 at 1 and 2.1 lb/acre.

Results of preliminary tests at College Station, Texas indicated that Chrysopa and Heliothis eggs can be sprayed on cotton plants successfully. Dacagin is promising as the thickening agent for these sprays. This technique could be used for starting populations of Chrysopa, and sterile Heliothis eggs could be used to maintain the populations in the absence of eggs from wild populations.

Chrysopa carnea Stephens eggs and larvae released in field cages at College Station controlled bollworms and tobacco budworms. Heliothis populations were reduced in various tests from 73.8 and 99.5%. A very large population of alternate prey (aphids and mites) reduced the effectiveness of the Chrysopa in controlling Heliothis in certain experiments.

Campoletis perdistinctus showed good searching ability for tobacco budworm larvae in cage experiments at Brownsville, Texas. The parasite and tobacco budworm adults were released on cotton in a 0.4 acre cage. Because of an unexpected low reproduction rate of the host, it was not possible to observe parasitism through successive generations, but a high parasitism of the F_1 generation (62 - 92%) resulted from weekly releases of both insects. The parasite demonstrated ability to find and parasitize a high percentage of a low host population.

Developmental periods of Lespesia archippivora (Riley), a tachinid parasite of the bollworm, ranged from an average of 46.7 days at 59° F to 13.8 days at 95° F at Tucson, Ariz. Optimum return of puparia occurred at a rearing temperature of 77° F. Survival of the puparia was poorest at 95° F. Lespesia archippivora preferred beet armyworm and salt-marsh caterpillar larvae when bollworm and cabbage looper larvae were also available. No imprinting of host preferences in F_1 flies from the various hosts was indicated. When the 4 species of hosts were offered separately to the flies, the flies oviposited readily on all of them.

In a study conducted under a grant by the Entomology Department, Auburn University, six bacterial and four fungal isolates have been taken from healthy mites. External fungi isolated from healthy spider mites included Aspergillus sp., Alternaria sp., Spondylocladium sp., and one undetermined isolate. No internal fungi were isolated from healthy mites. A large

number of dead mites with an associated mycosis were observed in collections from cotton in September. Cladosporium sp. was the most common fungus isolated from the mites. In addition, 6 bacterial and 12 fungal isolates have been taken from dead mites on cotton.

D. Insect Sterility, Attractants, and Other New Approaches to Control.

1. Boll Weevil. Female boll weevils responded to wind-borne pheromone from males in studies at State College, Miss. Males reared on cotton squares appeared to be more attractive than males reared on artificial media. Traps baited with extracts of male weevils captured fewer females than traps baited with live males. Individual males on plants attracted more females than males in traps. As in laboratory tests, female weevils responded significantly less to sterile males than to untreated normal males. Response of previously mated female boll weevils to males caged in traps was much less than that of virgin females. When equal numbers of mated and virgin females were released in a field cage, only 20% of the females captured over a 19-21 day period had mated. In the 1st 2 to 4 days 26 virgin females and only 1 mated female were captured.

Neutrons appeared effective in sterilizing boll weevils in studies at Phoenix, Ariz. In preliminary tests neutron irradiation of newly emerged male boll weevil adults at dosages of 10,000, 5,000, and 2,500 rem produced complete sterility but did not appear to be otherwise detrimental.

In studies at Iguala, Mexico, by personnel of the Boll Weevil Research Laboratory, a solid wing Stikem coated trap and an oblique funnel trap were the most effective of several traps of various designs baited with boll weevil males or male extracts for trapping females in a 1/2-acre field cage. Traps baited with male extracts captured approximately one-half as many females as traps baited with live males. Average daily mortality of medium-reared reproductive female boll weevils in a large field cage was 20%. A large population of spiders within the cage probably caused most of the mortality.

In studies at the Boll Weevil Research Laboratory, bisabolol, a sesquiterpene alcohol from cotton not previously identified, was attractive to the boll weevil. Two other components, believed to be structurally related, were isolated in pure form. These three components probably account jointly for most of the attractiveness of the cotton plant to the boll weevil.

Results of a genetics study of diapause in the boll weevil at the Boll Weevil Research Laboratory indicated that alleles that suppress diapause are dominant. A strain (M) of weevils with a high ability to diapause was crossed in the laboratory with a strain (S) with a low ability to diapause. F_1 progeny showed 3 statistically different sets of diapausing percentages. The M strain had a much higher percentage than the S strain, while the F_1 crosses approached the low diapausing strain in the

percentages attaining diapause. When the parental, F_2, and backcross progeny were exposed to the same stimuli, the backcrosses to the M strain increased in their ability to diapause while backcrosses to the S strain decreased in their ability to diapause and were not different from the S strain.

In studies at the Boll Weevil Research Laboratory, boll weevil males irradiated with 6388 rads of gamma radiation were equal in mating competitiveness for 5 days post irradiation with unirradiated males of the same age. On day 7, treated males were 10% less efficient in mating and by day 13 essentially none of the irradiated males would mate. Most of the treated males died between 9 and 13 days after irradiation.

Mixed sex groups of irradiated weevils were tested with normal weevils at ratios of 10:1, 20:1, and 100:1 irradiated: normal at the Boll Weevil Research Laboratory. Only ratios of 20:1 and 100:1 gave any control of reproduction of untreated weevils. Even the high level of 100 irradiated pairs to 1 unirradiated pair was not sufficient to completely eliminate egg hatch.

Laboratory reared diapausing boll weevils were more tolerant than reproducing weevils to gamma irradiation in studies at Baton Rouge, La. Exposure of adults to 10,000 R resulted in a 50% mortality of reproducing weevils after 2 weeks compared with a 50% mortality of diapausing weevils after 4 weeks. All weevils were held at 23° C following treatments.

Diapausing boll weevils, diapausing thurberia weevils and Gast strain laboratory weevils (non-diapausing) were irradiated with 6916 rads of gamma radiation in studies at the Boll Weevil Research Laboratory. The diapausing weevils showed a lower rate of mortality 10 and 15 days after treatment than non-diapausing weevils. After 20 days the diapausing boll weevils had almost equalled the Gast strain in mortality but about 50% of the thurberia weevils continued to live. Irradiated females laid no eggs during the 20 day period. When irradiated and non-irradiated weevils of both sexes were placed together in competition tests, no reduction in hatch was shown at 10, 15, or 20 days unless the ratio exceeded 10 irradiated pairs to 1 unirradiated pair. Even at ratios of 11:1 and 20:1 there were only very slight reductions in fertility.

A bait formulation containing a chemosterilant applied every 5 days to cotton in a large field cage at Iguala, Mexico, gave a high degree of sterility in an introduced boll weevil population in a study by personnel of the Boll Weevil Research Laboratory. Sterility, measured by hatch of eggs laid in squares, averaged 83%. Although this was not enough to prevent population buildup, the chemosterilant bait reduced the population considerably below that of the check.

Research was conducted under contract by the Southern Research Institute, Birmingham, Ala. on the isolation of boll weevil feeding stimulants found in flower buds and flowers (blooms) of cotton plants. The presence of a highly polar feeding stimulant component, or components, in squares and flowers that are distinctly different from biologically active, non-polar components in the same plant was demonstrated. This component is not due to hydrocarbons, carotines, carotenoids, porphysins, terpenes, perpenoids or flavonids. It is apparently (also) not due to proteins. Since the activity remains after extraction with methanol and ethanol, it is apparently attributable to poly-hydroxylated compounds. Porphyrin containing fractions with moderate feeding stimulant activity was obtained. Pheophytin a and b fractions were isolated from cotton squares in at least 90% purity and showed consistent activity. Acetone extracts of cotton squares also yielded active fractions in solvent partitioning studies and after thin layer chromatography.

2. Pink Bollworms. Sex lure traps failed to control pink bollworms in a 6-acre field in tests in Mexico conducted by personnel of the Brownsville, Texas, laboratory. Sixty traps containing crude-natural sex attractant were spaced 75 feet apart in 5 rows. They were serviced weekly. A total of 443 males were trapped. The estimated percentage of the male population trapped during weeks ending July 6, 13, 20, and 27 was 17, 5, 6, and 5 percent, respectively. Total pink bollworm-infested blooms and bolls ranged from 777 for the week ending June 22 to 6497 for the week ending August 3.

Sex lure traps were equally effective in trapping pink bollworm moths when installed at different heights at Brownsville, Texas. When four 1-qt ice cream containers were suspended in a field cage 0,3,6, (plant level) and 8 1/2 ft above ground level, there was no significant difference at the 5% level between the number of males caught per trap per night in the 3 traps located above ground level. Differences in catch were significant at the 1% level between the trap on the ground and those suspended above the ground level.

In tests at Phoenix, Ariz., neutrons appear effective in sterilizing pink bollworm adults. In preliminary tests neutron irradiation of mature pupae at dosages of 10,000, 5,000, and 2,500 rem produced sterility in the adults and did not appear to be otherwise detrimental.

Pink bollworm populations were reduced in cages with blacklight-sex lure traps at Brownsville, Texas. Results of a cage test indicated that blacklight (15 watt) traps baited weekly with a sex lure concentration of 1025 female equivalents (25 FE of the natural lure plus 1000 FE of propy-lure) reduced the total population by 46%. The total number of larvae in blooms and bolls for the check and the light-lure cages were 20,605 and 11,139, respectively. A total of 4872 moths (male and female) were caught in the light-lure trap.

E. Evaluation of Equipment for Insect Control and Detection

1. Boll Weevil A simple inexpensive technique was developed at State College, Miss., for capturing spray droplets from ultra-low volume insecticide formulations. A liquid matrix consisting of a cellulose gum and surface active agents will capture and suspend ULV spray droplets ranging in size from 1 micron to over 20 microns in diameter. The droplets stay suspended as perfect spheres for as long as two hours.

Results of field tests with a flail machine for destroying fallen boll weevil infested cotton squares showed control equal to that obtained with insecticide in tests conducted by personnel of the Boll Weevil Research Laboratory. Approximately 24 acres were treated from 5 to 7 times with the flail machine on a 7-day schedule. The square pickup efficiency for the season averaged 95.3%. Measurements of the force required to pick up a square showed that when squares were imbedded in soil by rain, as much as 76 times the weight of the squares was required to break it loose from the soil. The flail treated fields were compared throughout the season in a replicated experiment with fields treated with azinphosmethyl applied ultra-low volume at 0.125 lb/A, at 5 day intervals. Boll weevil control was comparable as long as cotton plants were small enough to permit flail treatments. After flail treatments had to be discontinued because of mechanical damage to the cotton plant, insecticide treatments were used to protect the crop for the remainder of the season.

Gound equipment for applying insecticides in ultra-low volume sprays consisting of mist blowers, rotary disc and pneumatic type sprayers were tested against boll weevils at Florence, S. C., State College, and Stoneville, Miss., Tallulah, La., and Waco, Texas. In general, the same amount of an insecticide applied in ultra-low volume gave as good or better control of the boll weevil as that amount applied in conventional sprays. All of the ultra-low volume spray equipment needs improvement.

2. Bollworms. Fewer bollworm moths were collected in a black light trap at Waco, Texas, in 1966 than in any previous year. Only 1,859 bollworm moths were collected in a black light trap during 1966-- the lowest number for any year from 1956 to 1966. In 1965, 1964, and 1963, 4,105, 7,215, 30,056 moths, respectively, were collected during the same period. In 1966, 6.5% of the moths collected were the tobacco budworm. This compares with 15.6% in 1965, 1.1% in 1964, and 9.0% in 1963.

Collections in black light insect traps indicated Heliothis zea populations peaked in August and September in South Carolina. Heliothis zea moths caught in black light traps operated from June 1 through September 25, 1966, indicated population peaks in mid-August and mid-September. Moonlight intensity of 14×10^{-6} watts/cm^2 was sufficient to inhibit moth movement and this or higher intensity occurred on June 1 and 2, July 31, August 1, 2, 28, 29, 30, and September 1. Moth catches on these nights were low.

Results of field tests at Florence, S. C., indicated that pulsed ultrasound did not control Heliothis zea in cotton. In field test, ultrasound was not an effective physical stimulus in preventing bollworm moth movement into a cotton plot. The ultrasound had a frequency of 20 KHz, pulse rate of 10 per second, and pulse duration of 10 msec. It was absorbed and reflected by the cotton foliage which limited its effectiveness to the airspace above the cotton. Heliothis zea moths evaded the airspace over the ultrasound test plot but exhibited normal behavior patterns of feeding, mating, and ovipositing while in the sound shadow produced by the cotton plants. However, the thesis that pulsed ultrasound has a repelling effect on H. zea moths in the field was substantiated by this study.

Results of field tests at Florence, S. C., with a combination ultrasound and black light insect trap showed that sound of a frequency of 20 KHz, pulse rate of 10/sec and pulse duration of 10 msec repels Heliothis zea moths. A combination ultrasound and black light insect trap was designed to determine the most efficient combination of pulse rate and pulse duration for eliciting H. zea evasive responses under field conditions. A sound frequency of 20 KHz, pulse rate of 10/ second and pulse duration of 10 msec was the most efficient combination of the ultrasound variable. Pulse rates of less than 4/sec were not as effective as those greater than 4/second.

Ground equipment for applying insecticides in ultra-low volume sprays consisting of mist blowers, rotary disc and pneumatic type sprayers were tested against bollworms at Florence, S. C., Stoneville, Miss., Tallulah, La. and Waco, and Brownsville, Texas. In general, the same amount of an insecticide applied in ultra-low volume gave as good or better control of the bollworm as that amount applied in conventional sprays. All of the ultra-low volume spray equipment needs improvement.

3. Pink bollworm. A black light trap was operated at Waco, Texas, from March 4 to December 1, 1967. The first pink bollworm was collected on May 23. The monthly numbers of moths collected were as follows: May, 1; June, 0; July, 0; August, 30; September, 556; October, 436; and November, 22.

4. Other Insects: Moths collected in 1966 in the black light trap operated at Waco were as follows: Cotton leafworm, 636; armyworm, 5,037; fall armyworm, 246; beet armyworm, 419; yellow-striped armyworm, 768; black cutworm, 199; pale-sided cutworm, 168; variegated cutworm, 1226; granulate cutworm, 1395; salt-marsh caterpillar, 60; and cabbage looper, 1529.

F. Varietal Evaluation for Insect Resistance

1. Boll Weevil. In studies at the Boll Weevil Research Laboratory, bolls from the glandless counterpart were damaged by boll weevils to a greater extent in 4 pairs and the glanded counterpart in 7 pairs of 12 glanded and

glandless cotton lines studied. Three pairs were damaged equally. This indicated that boll weevil response is influenced by the genetic background into which the glandless genes are placed.

2. Bollworms. Gossypol retarded development of Heliothis larvae in studies at Brownsville, Texas. In cage tests, larvae of H. zea and H. virescens that developed on three lines of cotton with high gossypol content weighed 24 to 58 percent less than those developing on a commericial glanded line.

Cotton pigments had little effect on food utilization in Heliothis virescens in studies at Brownsville. Food utilization was reduced 2.8 to 6.3 percent in H. virescens larvae with 0.1 percent gossypol, 1.5 to 3.7 percent with 0.15 percent rutin, and 1.5 to 7 percent with 0.1 percent quercetin in the diet.

At Brownsville, glabrous cotton strains reduced bollworm and cotton fleahopper populations. Glabrous experimental cotton strains were effective in reducing bollworm egg and larval populations below those on corresponding hirsute strains in replicated small plot tests in a 1/2-acre cage and in the field. This confirmed previous findings indicating that smooth surfaces were unfavorable for oviposition of the bollworm moth. In another experiment with replicated treatments in 1/3-acre plots, strain 1514 (glabrous) had a significantly lower fleahopper population than Deltapine Smoothleaf which is semihirsute.

3. Other Insects. Glabrous strains of cotton derived from different Gossypium species were equally resistant to the cotton fleahopper and cotton aphid. Glands or nectarines did not influence populations of the two insects.

321 OP variety of cotton was resistant to the cotton fleahopper in a field test at Waco, Texas. In a small-plot field test there were significantly fewer cotton fleahoppers on the 321 OP variety than on Coker 413 and Lankart 57 varieties. There was no difference between 321 OP and treated Lankart 57 or between Coker 413 and Lankart 57 untreated varieties.

In tests in Phoenix, Ariz. only two of thirty radiation induced mutant lines of cotton of Delta and Pineland variety showed resistance to lygus bugs in the seedling stage. One of these plants and an untreated DPL plant each were subjected in the 8-leaf stage to 5 lygus bugs for 10 days. The mutant plant produced a normal amount of squares but the untreated plant produced no squares.

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AREA NO. 10. TOBACCO INSECTS

Problem. Insecticides employed to control insects that attack tobacco, particularly budworms, hornworms, flea beetles, and aphids, may cause undesirable residues on cured tobacco. These residues adhere to the leaf through commercial processing and some have been found in the mainstream of smoke from commercial cigarettes. Non-insecticidal methods for controlling insect pests of tobacco are urgently needed. Research on lures, light traps, sterilization techniques, other new approaches to control, and better utilization of predators, parasites, and diseases of tobacco insects should be intensified. Studies to find market-acceptable tobacco varieties that resist insect attack need more attention. Integrated control programs that lessen the possibility of undesirable residues should also be investigated more intensively.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic and applied research on tobacco insects to develop effective control methods that will alleviate the residue problem on the harvested leaf. The research is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway and with the tobacco industry. Studies are conducted at Oxford, N.C., Florence, S.C., Quincy, Fla., and at a temporary location on St. Croix, Virgin Islands, a satellite of Oxford. Contract research supported by the Department is in progress at Kentucky, North Carolina, and South Carolina Agricultural Experiment Stations, and the Virginia Polytechnic Institute. A grant for studies on tobacco insects at the Clemson Agricultural Experiment Station in South Carolina and for work on tobacco flea beetles by the University of Florida Agricultural Experiment Station at Quincy have been implemented.

The Federal scientific effort devoted to research in this area totals 7.4 professional man-years. Of this number, 1.3 is devoted to basic biology, physiology, and nutrition; 1.7 to insecticidal and cultural control; 0.3 to insecticide residue determinations; 1.4 to biological control; 2.0 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.2 to varietal evaluation for insect resistance; and 0.4 to program leadership.

In addition Federal support of research under contracts and grants provides 0.4 man-year in this area. This is devoted to basic biology, physiology, and nutrition.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 10.8 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Tobacco Budworm. The artificial diet developed by Berger (ARS-33-84), which has been used to rear the tobacco budworm at Oxford, N.C., has been estimated to cost about $1.74 per gallon. Preliminary tests have shown that casein, one of the main ingredients of Berger's diet, can be replaced by MNC(R), a dairy product of Foremost Dairies, Inc. Use of this product has lowered the cost of the diet to $1.05 per gallon.

Experiments now in progress indicate that when MNC is used in place of casein there is no longer a need for choline chloride or the salt mixture. Elimination of these ingredients will also help reduce the cost of the artificial diet.

At Quincy, Fla., 1 and 2-day-old laboratory-reared tobacco budworm moths were marked on the forewing with paint and released in the center of a 1-square-mile area in which 60 blacklight traps were distributed. Six percent of those released were recaptured in the square mile and 72% of the captures were taken the first night after release. Several moths were caught up to 7 days after release. A rearing facility has been completed at Quincy, Fla., to produce cabbage looper and tobacco budworms on a synthetic diet. Present equipment will allow production of approximately 5,000 of each species weekly.

2. Tobacco Hornworm. At Oxford, N.C., a study of 3 different substrates, dry paper toweling, wet paper toweling, and artificial diet, showed that the best hatch (greater than 70%) is obtained on a dry substrate. The wet substrate yielded a hatch that was 50% less and the artificial diet less than 50% of the wet substrate. By autoclaving the papers on which the eggs are placed and by treating the eggs with a 15-minute dip in sodium hypochlorite (0.5%) and placing these items in a plastic cup that has also been treated with sodium hypochlorite, it has been possible to increase hatch nearly to 90% and to maintain 75% recovery during the time the larvae remain in the plastic containers.

In a study of movement of tobacco hornworm moths on Hatteras Island, North Carolina, approximately 2,000 moths have been marked and released at distances from 0 to 12 miles from blacklight insect traps. Only one recapture has thus far been made. Four unmarked wild moths were captured, one on the mainland at Stumpy Point and 3 on Hatteras Island, near Rodanthe, N.C.

On St. Croix, Virgin Islands, recovery of marked moths indicated that dispersal was primarily in random directions, although flights across or into the wind predominated at times. Males released at varying distances and directions from caged virgin females frequently flew upwind to find the females. Upwind dispersal was believed to be predicated upon the perception of attractive odors. One flight of 14 miles in 2 nights was recorded.

Males of the St. Croix strain of tobacco hornworm were attracted to North Carolina females on the island of St. Croix, suggesting that a synthetic pheromone derived from North Carolina females can be used in an eradication feasibility trial on St. Croix. Placement of virgin female tobacco hornworms on or near light traps appreciably increased the number of males collected in the traps.

On St. Croix the hornworm undergoes a resting stage similar to diapause. Some prepupae placed in ground cages in October did not emerge as adults until the following May.

At Oxford, N.C., the entry of the hornworm larva into the soil was found to be accomplished by a combination of scooping movements of the head capsule and compression of the anterior region of the body into the depression thus formed, followed by extension of the body region anterior to the abdomen through a series of hydraulic ramming motions. The tunnel thus formed in front of the advancing head capsule is widened to accommodate the greater width of the body by the larva swinging the head from one side of the median line to the other. The angle of entry is oblique; twenty-five measurements made with a protractor lay within a range of 41 to 53 degrees. After the body is submerged, an abrupt geotactic orientation is made, and the descent continues in a vertical line if the substrate does not become packed too hard. Soil structure when unfavorable cause the larva to turn aside and a zig-zag route to pupation site is the result. Very few larvae of 100 observed made a perfectly vertical descent to pupation site presumably because of soil irregularities.

The behavior of mature hornworm larvae prior to entering soil was studied at Oxford, N.C. Shortly after the fifth instar larva ceases feeding and prior to burrowing into the soil it executes a series of maneuvers. First it rears up on the back pair, or back 2 pairs of thoracic legs, and makes chewing motions while holding the body rigid and motionless for as long as 2-3 minutes. The head is deflected sharply toward the ventral surface, and a viscous fluid exudate flows from the mouthparts between the labium and neck. The head is swung in a lateral arc and, in a series of short, jerky movements, the mouthparts are brought into contact with the body. The dorsal region of the head capsule is brought into firm contact with the dorsal surface of the body. Fluid which was previously deposited is forced between the opposed surfaces and flows over the dorsal surfaces of the thorax and head capsule. The mouthparts are applied to the ventral region of the first abdominal segment and moved in a series of short, recurrent arcs over the lateral surface and the dorsal region of the segment. This series of "licking" movements is continued to the last segment of the abdomen and the anal prolegs. The body is straightened and the process is repeated.

This fluid may act as an antibiotic and/or a moisture proofing coating, helping to prevent water loss during the period of chrysalis formation. It hardens upon exposure to the air and is soluble in the fluid which is exuded from the mouth.

Survival of pupae and size and vigor of the emerging adults appeared to be directly related to soil moisture. Partial desiccation resulted in slow development and greatly staggered emergence. In many instances the wings were not properly inflated and wing deformity occurred. In drier soils the larvae also lost body fluids in the process of establishing themselves at pupation sites that are required for metamorphosis.

3. Cabbage Looper. At Quincy, Fla., catches of male cabbage loopers in light traps baited with and without synthesized sex lure identical in composition with that naturally produced by female cabbage loopers were correlated with mean night temperatures, maximum temperature on day preceding catch, minimum soil temperature on night of catch, sunshine on day previous to catch, relative humidity, barometric pressure, cloudiness, and air movement. These are the weather elements considered to have the greatest influence on insect activity. In traps with light alone, cloud cover increased catches more than any other factor; moonlight decreased catches. However, when the sex attractant was added to blacklight, trap catches were greatly increased irrespective of moonlight or cloud cover. Low humidity, high air and soil temperatures, and air movements increased catches in the combination blacklight and sex attractant traps.

Also at Quincy, Fla., captured male cabbage loopers were marked and released in the center of a 1-square-mile test area. In this experiment 60 blacklight traps each were baited with 0.1 gram of the female looper sex lure. Ten percent of the marked moths were recovered; about 95% of the recaptures were taken in the 41 traps within the square-mile test area. Several moths were recaptured 3 to 4 miles from the release point and one was recaptured 13 miles away 2 days after release. A few moths were recaptured 7 days after release.

B. Insecticidal and Cultural Control

1. Wireworms. At Florence. S.C., a method was developed for control of wireworms in tobacco fields, employing a granular insecticide distributor attached to a tractor in such a way that the tractor would simultaneously apply granules as a row treatment and bed the row. Standard tractor equipment was used.

Field experiments have demonstrated that several new insecticides are effective wireworm control remedies when applied as granules. The most effective materials have been Bay 37289, Stauffer N-2790, Union Carbide UC 21149, Mobil V-C 9-104, a diazinon corn grits bait, Niagara NIA-10242, Chevron RE-5305, and Bay 25141. In cooperative work with the Crops Research Division, UC-21149 and Mobil VC 9-104 have also shown promise as a control remedy for the root knot nematode which attacks tobacco.

Disulfoton was an effective systemic insecticide for control of the tobacco flea beetle and green peach aphid on flue-cured tobacco when applied to the soil as a granule. Disulfoton has label registration for use on tobacco.

2. Green Peach Aphid and Tobacco Flea Beetle. At Florence, S.C., the most effective systemic insecticide for control of foliage feeding tobacco insects has been Niagara NIA-10242. This chemical when applied to the soil as granules has given good control of the tobacco flea beetle, the tobacco budworm, and the tobacco hornworm. The length of time the material remains effective has not been determined but has been effective for several weeks.

3. Tobacco Hornworms and Budworms. The influence of late season stalk cutting to prevent late season development of overwintering tobacco hornworm and budworm was continued in a 113-square-mile area at Florence, S.C. Growers cut 87% of their stalks in 1965 and 90% in 1966. The remaining stalks were cut by a commercial operator. Despite stalk destruction in 1966, a severe hornworm infestation developed in 1967 in the middle of the stalk cutting area. Hornworms produced throughout the tobacco growing area may have concentrated on this and other fields in which stalks were not destroyed in 1967. Movement of moths from outside the experimental area may also have been responsible for the infestation. Stalk destruction may need to be practiced throughout extensive tobacco-producing areas to be effective.

C. Insecticide Residue Determinations

1. Off-Taste and Flavor Studies. At Florence, S.C., there has been no off-taste or flavor in tobacco grown where the most promising soil treatments were used for wireworm control. The treatments have included a transplant water treatment containing diazinon wettable powder and granular formulations Bay 37289, Bay 25141, Stauffer N-2790, Union Carbide UC 21149, Mobil VC 9-104, and a 4 lb active ingredient rate of Niagara NIA-10242.

D. Biological Control

1. Cabbage Looper. At Quincy, Fla., application of a commercially prepared nuclear polyhedral virus as a dust on cigar wrapper tobacco for control of cabbage loopers was as effective as the standard insecticide treatments.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Tobacco Hornworms and Budworms. At Oxford, N.C., hornworms were effectively sterilized with 35,000 rads of cobalt 60 irradiation administered late in the pupal stage. Field released sterile males dispersed and survived well; however, natural populations during the initial releases were low and meaningful sterility data were not obtained.

A flight chamber measuring 80' x 8' x 8' has been constructed at Oxford, N.C., and automatic humidity, temperature, and light control systems installed. A modified blacklight trap at one end of the chamber was equipped with an hourly sample changer so that the trap could be timed to run for any period up to 12 hours with samples collected automatically for each 12-hour period. The highest catch of diet reared male moths was 58% and occurred on the first day. The average catch of diet-reared males over a 4-day period was

40.5%. The highest catch of field-reared males was 38% and occurred on the second day. The average catch of field-reared males over a 6-day period was 25.5%. The highest catch of diet-reared virgin female moths was 17% and occurred on the second day. The average catch of virgin females over a 6-day period was 7.5%, which compares favorable with the 3.6% total of virgin female moths that were captured in 78 check traps in the integrated control area surrounding Oxford.

On St. Croix, Virgin Islands, about 250 UV light traps were in operation for they year to measure their effect on isolated insect populations. Thrice weekly counts of collections from 53 of these traps were made. Included in the counts were the tobacco hornworm, the tobacco budworm, the corn earworm, stink bugs, May beetles, and other insects, totaling over 30 species. The trapping appeared to suppress the populations of several species but did not eradicate them. For 6 months 11 plots of tobacco, corn, sugarcane, cucumber, cotton, and cabbage were maintained at representative locations on St. Croix to determine the density and distribution of insects attacking these crops and the effect of the light trap installation on population densities. The melonworm, pink bollworm, corn earworm, and fall armyworm were found to be abundant whenever suitable host material was present. Insects from 17 traps maintained on the islands of Culebra and Vieques near Puerto Rico and on St. John and St. Thomas in the Virgin Islands were collected and counted 3 times a week. The information obtained will serve as a basis for evaluating the control potential of blacklight and other population suppression measures involving integrated use of physical and chemical attractants, natural enemies, and other methods.

At Florence, S.C., field trap cage studies during 1966 and 1967 demonstrated that a chemical extract of a crude sex attractant is attractive to male tobacco hornworm moths. The chemical extract was prepared by the Zoology Department of the University of Wisconsin working under Entomology Research Division grant No. 12-14-100-7991 (33). The quantitative potency of this promising chemical extract has not been determined. It was obtained from a crude extract of virgin female tips clipped into ether, a process initiated at Florence in 1961.

At. Quincy, Fla., in a 1-square-mile area containing 41 blacklight traps, each baited with 0.1 gram of the female cabbage looper sex lure (100,000 female equivalents), male populations were drastically reduced. However, the number of mated females, eggs, and small larvae and percent egg hatch were not significantly less than in outside areas with 3 light traps per square mile.

2. Integrated Control. At Quincy, Fla., further evaluation of an integrated insect control program using disulfoton, light traps, the pathogen Bacillus thuringiensis and relatively nonpersistent insecticides as needed, reduced the number of insecticide applications on cigar wrapper tobacco by about 40%.

F. Evaluation of Equipment for Insect Detection and Control

1. Blacklight Traps. On St. Croix, Virgin Islands, battery operated blacklight traps collected as many hornworms as power line operated traps, despite the lower light intensity of the former, attesting to the reliability of data from experiments that included battery operated traps. Other insects that were equally or more attracted to the battery operated traps included May beetles, stink bugs, tobacco budworm, corn earworm, and Pseudoplusia includans.

The presence or absence of dead insects in the light trap collection baskets on St. Croix, Virgin Islands, did not affect the collection of hornworm moths. Fewer tobacco budworms and corn earworms were collected in baskets that were half full of dead insects.

There did not appear to be any interaction between iso amyl salycilate, a tobacco hornworm attractant, and the ultraviolet light of the traps. Collections of the tobacco hornworm and 6 other sphingids was not influenced by the chemical.

At Quincy, Fla., in cooperation with the Agricultural Engineering Research Division, 1, 2, 3, and 4 15-watt blacklight traps were baited with 0.1 gram of the female cabbage looper sex lure. Increase in wattage failed to improve the male cabbage looper catch; however, tobacco budworm and corn earworm catches increased with wattage.

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AREA NO. 11. SUGARCANE AND SUGARBEET INSECTS

Problem. Control of insects on sugarcane and sugarbeets is essential because of destructive plant diseases spread by insects and damage caused. The use of insecticides for insect control requires special care to avoid contamination of the harvested product with undesirable residues. Safe effective methods of control are especially needed for the sugarcane borer, the sugarbeet root maggot, and the beet webworm. Sugarcane mosaic has become more important in recent years, and information on insect vectors of this disease is needed. Beet yellows and associated western yellows virus diseases of sugarbeets continue to threaten the sugarbeet industry. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. Studies on the ecology and methods of control of the weed reservoirs of the insects that transmit the two viruses should be continued. For long-range solutions to these problems, further investigations should be undertaken to find effective parasites and predators of sugar-crop pests and to develop varieties of sugarcane and sugarbeet that are resistant to insect attack. The usefulness of destruction of alternate host plants and new approaches to insect control, such as the male sterility technique and attractants, should be investigated. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make the natural control of other pests on the same crops difficult are special problems that should receive emphasis in the search for nonchemical methods of control.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. This program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway and with industry. Studies on sugarcane insects are conducted at Houma, La., and Canal Point, Fla.; and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, and Yakima, Wash. Research on factors affecting the efficiency of Trichogramma spp. as parasites of lepidopterous pests is being conducted under a research grant with the Louisiana State University. Research on reproduction of beet leafhoppers is conducted under a grant in California. Cooperative agreements are being used to support research in North Dakota on control of sugarbeet root maggot and in Washington on plant resistance to yellows and its vectors.

The Federal scientific effort devoted to research in this area totals 9.5 scientists man-years. Of this number 1.6 is devoted to basic biology, physiology, and nutrition; 2.5 to insecticidal control; 0.7 to insecticide residue determinations; 1.7 to biological control; 0.4 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of

equipment for insect detection and control; 0.6 to varietal evaluation for insect resistance; 1.0 to insect vectors of diseases; and 0.7 to program leadership.

Federal support of research in this area under grant provides for 0.3 professional man-year devoted to biological control, and 0.3 to basic biology of the beet leafhopper and under cooperative agreements for 0.3 man-year for control of sugarbeet root maggot and in cooperation with Crops Research Division for 0.3 for resistance studies.

Natural enemies of the sugarcane borer in India are being studied under a PL 480 project A7-ENT-1, by the Commonwealth Institute of Biological Control, Bangalore, India. Parasites and predators found effective for borer control will be made available foruse in the United States. A second PL 480 project, A7-ENT-22 has been initiated in India on studies of Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 5.4 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Sugarbeet Insects. At Twin Falls, Idaho, field studies near Rupert showed that most sugarbeet root maggots overwinter in the larval stage 6 to 9 inches below the soil surface. Root maggot flies emerged from the soil from May to August, the peak of emergence occurring in early June. This information provided basic information useful in timing field insecticide applications for control of adults of this pest insect.

Raw sugarbeet juice was more effective than other attractants used in the fly trapping. Other partially effective attractants were processed beet juice obtained from the sugar factory and a sugar solution. Male root maggot flies were sexually aggressive on the day of emergence whereas females were not receptive to mating until 3 days after emergence even though the newly emerged female flies contained a full complement of mature-sized eggs.

At Yakima, Wash., the ephydrid leaf miner, Psilopa leucostoma, a newly discovered pest of sugarbeets was found to attack the Halberd-leaved Orache, a saltbush, Atriplex hastata, and the common lambsquarters, Chenopodium album, and occurs throughout the intermountain region both in and outside of sugarbeet production areas.

At Yakima, a D-Vac(R) suction-type insect collector collected 6 times as many beet leafhoppersfrom sugarbeets as the standard sweep-net method. Sixteen kinds of leafhoppers were collected from sugarbeets. The beet leafhopper was most abundant and comprised 35% of the leafhopper population in July.

At the University of California, under USDA grant, a method was developed to differentiate sex of beet leafhopper nymphs based on the pattern of sclerotization of the ventral surface of the posterior abdominal segment.

2. Sugarcane Insects. In Louisiana the sugarcane borer infestation at harvest time in 1966 was 14% of the internodes bored or 4% less than 1965. Estimated crop loss due to borers was 11%. However, more borers overwintered in 1966-67 than normal due to an excessive amount of cane tops left in the field because of a severe freeze.

The sugarcane borer infestation in Florida (internodes bored) was 2.4% in 1966. This is slightly less than in the previous year.

Wireworms have become the most destructive sugarcane pests in Florida, and they caused serious reduction in stand of plant cane.

B. Insecticidal and Cultural Control

1. Sugarbeet Insects. Screening tests at Twin Falls, Idaho, against sugarbeet root maggot adults showed Bay 39007, diazinon, and azinphosmethyl to be the most promising insecticides for the control of this insect. These same insecticides were tested under field conditions near Rupert, Idaho, against flies of the sugarbeet root maggot and all gave promising results. Also several granular materials applied in a 6-inch band at planting time gave good control of the maggots. Granules of phorate and diazinon gave the best control but Bay 25141, Bay 37289, and Stauffer N-2790 were also effective.

An isolated area of 584 acres of sugarbeets near Rupert, Idaho was sprayed three times by airplane with undiluted technical malathion at the rate of 8 ounces per acre for control of root maggot flies. The sprays reduced the ensuing maggot population by 73% over the total area; maggots were reduced by nearly 100% in some fields. The first spray was applied 9 days after the first flies emerged. Results probably would have been much better had the weather permitted earlier application.

Two 1-lb applications of phorate, disulfoton, and Temik to the foliage of sugarbeets controlled aphids and increased yields 1 ton per acre at Yakima, Wash. This was of particular interest since the experiment was located within a 22 mi^2 area where overwintering forms of the green peach aphid and sources of beet western yellows had been drastically reduced by burning out overwintering hosts of aphids and virus in deep irrigation drains.

Curly top, transmitted by the beet leafhopper, caused more than the usual damage to sugarbeets in eastern Washington in 1966 and 1967. Curly top was most prevalent in late plantings. Foliage applications of phorate were more effective than demeton, disulfoton, oxydemetonmethyl, or Temik for control of the beet leafhopper.

Phorate proved more effective than disulfoton, demeton, oxydemetonmethyl, or Temik for control of the two-spotted spider mite on sugarbeets at Yakima, Wash. Although aphid treatments are applied in May and June, additional applications are required in July or August for mites. Foliage applications of Temik granules to sugarbeets gave better control of the green peach aphid and the potato aphid than disulfoton, phorate, demeton, or oxydemetonmethyl. In 1966, the green peach aphid was most abundant early in the season and the potato aphid the last half of the season. Temik also controlled lygus bugs for nearly 15 weeks and leaf miners for 21 weeks.

Experiments at Yakima, Wash., showed that the defoliation of peach trees the latter part of September with chemical defoliants reduced egg laying of the green peach aphid by 73%. The reduction caused by abscission of leaves before the oviparae aphids had crawled to the twigs was further augmented by increased syrphid predation.

2. Sugarcane Insects. Sixteen compounds were evaluated against the sugarcane borer, Diatraea saccharalis, in Louisiana. Percentages of control based on reductions in number of bored joints (internodes) ranged from 0 to 93. New insecticides showing the most promise for future use in the borer control program are American Cyanamid 47480, Dow M-3072, and Niagara NIA-10242 in granular formulations, and Abate, Azodrin, General Chemical GC-6506, and Shell SD-8447 in spray formulations.

Azodrin and azinphosmethyl both at 1/2 and one pound per acre for each of two applications as ultra low volume concentrates in an airplane experiment in Louisiana gave controls of 77 and 87% for Azodrin and 63 and 77% for azinphosmethyl at the respective dosage rates. Diazinon at one pound per acre gave only 23% control.

A survey of Azodrin-treated fields scattered over the sugarcane area of Louisiana showed infestations of less than 10% in 17 fields, with an average of 6.4% for 21 fields examined.

A comparison of automatic schedules of insecticide applications with a schedule of applications made when weekly examinations show 5% or more of the stalks infested with larvae feeding behind the leaf sheath showed no significant difference between the two methods, even though the number of applications were the same. These results are based on two years work and five field experiments in Louisiana.

Populations of the yellow sugarcane aphid (Sipha flava Forbes) increased enormously in Louisiana fields treated with carbaryl for borer control, regardless of dosage rates and formulations.

Studies of 10 insecticides for control of wireworms in Florida show the following 4 to be most promising: Stauffer N-2790 10% granules at rate of 3.8# active material per acre, Shell SD-9098 EC @ 4#, Niagara NIA-10242 10% granules @ 3.8#, and diazinon EC @ 4#. Results of 4 tests indicate little if any resistance of wireworms to parathion.

C. Insecticide Residue Determinations

1. Sugarbeet Insects. At Yakima, Wash., DDT, aldrin, and chlordane were applied in various doses to soil in 1965 but were not applied in 1966. One and a half years after application, the soil residues found were the following percentage of the initial residues: Aldrin (and dieldrin) 13, DDT (isomers and metabolites) 13, chlordane (isomers) 33. Residues in the harvested beet roots, calculated in terms of parts per million of residue in the roots for 1965 and 1966, respectively, were: Aldrin 0.04 and 0.003, DDT 0.013 and 0.008, chlordane 0.013 and 0.008.

D. Biological Control

1. Sugarbeet Insects. A big-eyed bug, Geocoris sp., was responsible for more than 50% mortality of eggs of the spinach leaf miner, Pegomya hyoscyami, on sugarbeets but this predator rarely attacked eggs of the ephydrid leaf miner, Psilopa leucostoma, at Yakima, Wash.

2. Sugarcane Insects. A small shipment of Trichogrammatoidea nana was received from the University of California for tests on the sugarcane borer in Louisiana. This species originally came from sugarcane borer eggs in India and is not known to occur in North America. It is particularly interesting since it and sugarcane may have evolved together. It readily parasitized eggs of our sugarcane borer, D. saccharalis, in the laboratory and parasitized 18% in a small field test.

In studies conducted at Louisiana State University under a grant, eggs of the sugarcane borer were unacceptable in the laboratory as a host by any of several strains of Trichogramma collected from various hosts. However, sugarcane borer eggs deposited naturally in the field were heavily parasitized.

Several Sycanus indagator, family Reduviidae, originating in India, were tested against larvae of the sugarcane borer in Louisiana. This predator readily accepted the borer and has been reared through one generation in the laboratory. The first field release is expected to be made in 1967.

Studies were continued of predaceous arthropod fauna in fields with past histories of high and low sugarcane borer infestations in Louisiana. In pitfall traps operated during the last three growing seasons, four general groups of predaceous arthropods were collected, namely: Ants, beetles, earwigs, and spiders. Ants, consisting of both native and imported fire ants appear to be responsible for low borer infestations.

More ants were always found in fields having low sugarcane borer infestations. For example, pitfall traps collected 312 ants in a field which had 6% internode infestation in 1965 compared to only 33 in a field which had 33% infestation and only one in a field with 50% infestation. When heptachlor was applied to a sugarcane field, ants collected in traps were reduced from 608 to 23. Fourteen weeks after treatment 36% of the joints in the treated field was infested as compared with 11% in the untreated field.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Insects. After laboratory tests showed that mating of the sugarcane borer occurred only below .04 foot candles of light, a small isolated cane field in Louisiana was flood-lighted in 1964, 65, and 66 to determine if the borer infestation could be reduced. As flashes of light were found to be just as good as constant light in the laboratory, tests were conducted under both conditions. Results indicate that neither constant or flashing light will noticeably reduce the borer infestation under field conditions.

The sugarcane borer is being successfully reared on an artificial diet at the Houma laboratory. Reared material is being used to increase parasites and predators in the laboratory for field release, and to infest cane varieties to determine their resistance to the borer.

F. Varietal Evaluation for Insect Resistance

1. Sugarbeet Insects. At Yakima, Wash., 4 of 31 varieties of sugarbeets were significantly more resistant to the beet- and beet-western yellows complex than the others. The variety grown commercially in eastern Washington was one of the four resistant varieties. The spinach leaf miner showed no particular preference for any of the 31 varieties tested. Three varieties showed some resistance to the green peach aphid.

2. Sugarcane Insects. Two hundred and eleven sugarcane varieties were tested for resistance to sugarcane borer in single plots under conditions of artificial infestation in Louisiana in 1966. Twelve of these varieties had infestations between 1/3 and 2/3 of average--yields from 50 to 187% above average. Variety C.P. 66-491 with less than a third of the average infestation and 50% greater yield looks best. It also appeared good in previous tests. The stalk is large and has a high sugar content. Two other varieties showing considerable promise are H-60-386 with an infestation of 46% of average and a yield of 187% above average, and H-57-571 with an infestation of 49% of average and a yield of 163% above average.

Two hundred progeny from basic crosses and backcrosses involving wild (S. spontaneum and S. robustum) and cultivated canes made at Canal Point, Fla., and grown at Houma, La., were examined for borer infestation in the fall of 1966. These ranged from resistant to very susceptible. Three were very resistant and 21 otherswere moderately resistant. These 34 varieties were planted in a resistance test where they were subjected to artificial infestation in 1967.

G. Insect Vectors of Diseases

1. Sugarbeet Insects. At Mesa, Ariz., controlled infestations of curly top-infective beet leafhoppers on plots of sugarbeets grown for seed were accompanied not only by losses in yield but also late spring infestations reduced the ,ercentage of viable seed.

A disease with symptoms similar to curly top was found in India (PL 480 project A7-ENT-22). Surveys for leafhoppers revealed the presence of several species of Circulifer.

2. Sugarcane Insects. Mosaic continues to be the most important disease of sugarcane in Louisiana. Since the disease is spread by insects, chemical control of insect vectors is being studied. In one experiment, 7 applications of diazinon and TDE reduced vector populations by 43 and 100% but had no effect on mosaic spread. In another test 4 applicationsof demeton gave 54% reduction in vector populations and reduced mosaic infection by 22%. Complete control of the rusty plum aphid, the only vector species for which sugarcane is a natural host, was obtained with all insecticides.

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AREA NO. 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites and by diseases spread by insects. Effective and safer control measures are needed for many of these pests. Knowledge of the distribution of insect pests of these plants and information on their biology and behavior are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable insecticidal residues are needed. The nature and cause of strains of insects and mites resistant to insecticides and means of overcoming or preventing resistance require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological, insecticidal, and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be given more attention. Increased emphasis should be placed on attractants, chemosterilants, and growth or reproduction-affecting substances.

USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N.Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N.J., and Geneva, N.Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and the Agricultural Engineering Research Divisions of ARS. Research on turf insects is also conducted under grant with the University of Florida.

The Federal scientific effort devoted to research in this area totals 8.9 scientist man-years. Of this, 1.0 man-years is devoted to basic biology and nutrition; 1.8 to insecticidal control; 0.4 to insecticide residue determination; 1.4 to biological control; 2.7 to insect sterility, attractants, and other new approaches to control; 0.7 to evaluation of equipment for insect detection and control; 0.1 to varietal evaluation for insect resistance; 0.2 to insect vectors of diseases; and 0.6 to program leadership.

In addition Federal support of research in this area under grant provides for 0.6 professional man-year devoted to insect sterility and attractants.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 13.8 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Flower Thrips. Migration studies of flower thrips based on wind vane stickycard traps showed peak flight periods during May 17-20 and June 28-July 5 at Fort Valley, Ga., and Beltsville, Md., respectively.

2. Orange Tortrix. At Sumner, Wash., when alfalfa meal was deleted from Ignoffo's cabbage looper diet all stages of growth and development of the orange tortrix slightly improved. However, when alfalfa meal was removed from Redfern's red-banded leaf roller diet, the larvae died in the first instar. Nutritionally the diets are the same except for wheat germ in Ignoffo's diet.

3. Bagworm Pheromones and Reproduction. In research under a grant to the University of Georgia, the origin of the bagworm pheromone has been shown by response of the male to be in the anterior portion of the female body.

4. Japanese Beetle. Studies at Moorestown, N.J., showed that female Japanese beetles remain in the soil for 7 to 10 days after transformation from pupae and then emerge from the soil. They begin to oviposit about 48 hours after emerging from the soil or 9 to 12 days after transformation from pupae.

A media containing alphacel, acetone powder, clover extract, protein, and a vitamin mixture sandwiched between black filter paper provided food for rearing Japanese beetle third-instar larvae to maturity. Addition and deletion of the different ingredients in the diet show that protein is needed for maintaining larvae in acetone-powder-base diets. Other ingredients that increased the percent of larvae that pupated and transformed to adults included cholesterol, Wesson's salts, vitamins, linoleic-linolenic acids, and choline chloride. The larvae feed on the cellulose in the filter paper and white paper has proved as satisfactory as black paper.

5. European Chafers. Observations made at Geneva, N.Y., showed that both males and females make more than one mating flight during their life span. Techniques were developed to determine sex of chafer larvae based on the presence of ampullae.

6. Cuban May Beetle. A method was developed to separate sexes of the Cuban May beetle under a grant to the University of Florida. Females showed a ninth tergite inside of the eighth. Two indentations resulting from this appear as dark spots. Emergence and flight patterns of this beetle are similar to those observed for the European chafer in New York. Cuban May beetles emerged from the soil at dusk when light meter readings were about 0.05 to 1.0 ft.-c. They left the trees in the early morning at similar meter readings.

B. Insecticidal and Cultural Control

1. Aphids. At Sumner, Wash., immersion for 2 minutes in benzene hexachloride or endosulfan at 1- and .5-pounds toxicant per 100 gallons of water controlled 2 aphid species 71 days after treatment.

UC-21149, phorate, disulfoton and Bay 25141 applied in the furrow at planting time at 2 pounds actual per acre failed to control completely tulip bulb aphids 7 days after harvest (11-1/2 months after application). However, higher aphid mortality occurred in bulbs from treated plots than on bulbs from untreated plots.

At Farmingdale, N.Y., UC-21149 granules applied to the soil surface of potted Easter lilies at 3- and 6-lb/acre killed all aphids on foliage within 13 days and showed a 99% reduction after 11 weeks. UC-21149 was more effective at the 13-day and 11-week periods than demeton or oxydemetonmethyl.

2. Citrus Mealybugs. At Farmingdale, N.Y., UC-21149 granules at 5- to 20-lb per acre gave the best control of 8 systemic insecticides tested for control of citrus mealybugs on coleus.

3. Omnivorous Leaf Roller. At Beltsville, Md., Dursban and Matacil were as good or better than Zectran for control of omnivorous leaf roller larvae on roses, but Dursban was phytotoxic. Azodrin was slightly less effective than Zectran.

4. Poinsettia Pests. At Beltsville, Md., (in cooperation with the Crops Research Division) foliage and bracts of two poinsettia cultivars were uninjured by 5 weekly applications of aerosols containing sulfotepp or dichlorvos and 3 sprays containing diazinon (0.25 lb), dimethoate (0.25 lb), and oxydemetonmethyl (0.25 lb). All materials tested controlled scales, mealybugs, and whiteflies, and dimethoate and oxydemetonmethyl also controlled two-spotted spider mites.

Binapacryl (0.25 lb), Hooker HRS-16 (0.25 lb), endosulfan (0.25 lb), parathion (0.25 lb), and malathion (0.6 lb) did not injure poinsettia foliage but caused necrotic spots in the bracts.

Morestan wettable powder left undesirable foliage residues and caused severe necrotic spotting of bracts. Dicofol caused reduction in size of leaves and bracts and a striking color change of bracts from red to pale pink.

5. Japanese Beetle. In field plots near Moorestown, N.J., surface applications of diazinon killed all overwintering larvae when applied during October 1966 using dosages as low as 8 lb per acre. Untreated plots averaged more than 4 larvae per square foot. Larvae were within 2 inches of ground level at time of application. Diazinon applied at 8 lb per acre late in the season following the normal oviposition period for adults can be depended on to control larvae 100%. NIA-10242 and MC-A-600 killed all overwintering larvae

present within 6 weeks when they were applied during April 1967 as surface treatments using either granular or wettable powder formulations. Larvae were near the ground level feeding at the time of application and about 6 inches of rainfall occurred during the 6-week period. Larvae in untreated plots averaged more than 5 per square foot.

At Moorestown, N.J., carbaryl in oil and naled were the quickest acting insecticides 24 hours after treating against Japanese beetles caged in a laboratory wind tunnel. Others that were very efficient included: Trichlorfon, malathion, DDVP, and ENT-27429. Mortality of beetles 48 hours after spraying showed the following order of efficiency: Carbaryl in oil, naled, azinphosmethyl, trichlorfon, dimethoate, Bidrin, and ENT-27429. At 72 hours after treatment the more effective formulations were rated in the following order: Carbaryl in oil, naled, azinphosmethyl, trichlorfon, dimethoate, Bidrin, ENT-27429, carbaryl WP, GS-13005, and diazinon.

6. European Chafer. At Geneva, N.Y., 2.5- to 5-lb Bay 37289 and Stauffer N-2790 gave 98 to 100% control of third-instar larvae within 4 weeks after exposure of larvae to soil containing 10-week-old treatments.

Ten-week-old field treatments using encapsulated diazinon at 5 lb/acre killed 74% of European chafer larvae exposed to it; whereas, less than 48% of the larvae were killed when exposed to the standard diazinon formulation.

In tests at Geneva, third-instar European chafer and Japanese beetle larvae were placed together in pots of soil treated with different dosages of insecticides. In later studies, the tests were repeated using first-instar larvae. It was found that larger dosages of insecticides were needed to control third-instar larvae of European chafer than for Japanese beetles. At least twice as much and in some instances much higher dosages were needed. It was also shown that third-instar European chafer larvae weighed twice as much as third-instar Japanese beetle. However, studies using first-instar larvae showed that both species of larvae were controlled with equal amounts (minute) of insecticides.

C. Insecticide Residue Determination

1. Field studies maintained at Geneva, N.Y., since 1965 show that dieldrin residues can be made inactive by applying activated charcoal. Bioassay shows that 70 to 80% of the Drosophila exposed 2 years following treatment to soil containing dieldrin at 0.6 lb/acre in 1965 were killed. Less than 0.9% of the Drosophila died when they were exposed to soil treated similarly with dieldrin then subsequently treated with 2490 lb/acre of activated charcoal.

D. Biological Control

1. Japanese Beetle. Two years' comparisons by Moorestown, N.J., personnel of granular and dust formulations of milky disease, Bacillus popilliae, from field plots in North Carolina show that the granular formulation is as effective for reducing Japanese beetle populations as the dust formulation.

Plots were treated in November 1964 with equal amounts of active spore dust. Spore concentrations are about equal.

At Moorestown, milky disease spores produced in vitro at the Northern Utilization Laboratory, Peoria, Ill., were found to be noninfective when fed to Japanese beetle larvae. Two other bacteria, Pseudomonas sp., supplied by the Insect Identification and Parasite Introduction Research Branch and Bacillus alvei, which is sometimes present in field-collected larvae, were also noninfective in laboratory studies.

2. European Chafer. Cooperative investigations at Moorestown and Geneva show that European chafer infested areas in western New York had an incidence of milky disease spores that ranged between 20 and 44%.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Aphids. At Sumner, Wash., aphid counts from yellow pan traps placed in aluminum foil mulched Iris plots showed a total of 76 aphids trapped from November 1966 through May 1967. Traps placed in unmulched plots for the same period caught 633 aphids. Aphid populations on Iris plants within the aluminum foil mulched plots were reduced 49% as compared to aphid populations in untreated check plots.

2. Omnivorous Leaf Roller. At Beltsville, Md., omnivorous leaf roller injury was greatly reduced on rose plants during a 70-day trapping period with a blacklight trap in a 12' X 14' greenhouse. The traps captured 390 males and 67 females. A total of 133 larvae and pupae remained on the plants in the greenhouse.

In a commercial rose greenhouse at Kennett Square, Pa., 10 blacklight traps baited with pheromone extracts of virgin females did not remove sufficient numbers of males from the greenhouse to reduce mating. Larval infestations on rose plants at the end of the study were sufficiently high to warrant chemical control.

3. Flower Thrips. At Beltsville, Md., aluminum foil mulch to repel thrips and 5 systemic insecticides to control these insects were compared for effectiveness in reducing thrips infestations on rose flowers. The mulch alone was so effective that it masked the effectiveness of the insecticides. However, flowers from UC-21149- and dimethoate-treated plants had consistently lower numbers of thrips when no aluminum was used.

4. Aphids. At Beltsville aluminum foil mulches in Unwin dahlia field plots resulted in 92% reduction of aphids trapped in yellow pans, 60% reduction of dahlia mosaic infection, and 67% increase in weight of roots at harvest.

5. Green Peach Aphids. At Purdue University, Lafayette, Ind., using a small test arena and electromagnetic energy across the wave length range of 350 to 700 mμ, apterous aphids demonstrated a decrease in response to monochromatic

light as wavelength increased. When given a choice between monochromatic energy and a standard "white light" both apterous and alate aphids were more sensitive than when monochromatic light was used alone. Aphids exhibited a reversal by showing a positive response to monochromatic energy at about 600 mμ which is near the wave length of orange color found by other investigators to be most attractive to aphids.

6. Japanese Beetle. Analyses made by Plant Pest Control Division personnel at Otis Air Force Base, Mass., and Moorestown, N.J., personnel recorded 2.0, 0.6, and 0.4 μg tepa remaining 1.5, 22.5, and 48 hours following treatment of Japanese beetles by dipping in 0.062% tepa for 10 seconds. At Moorestown one of 10 triazine compounds, ENT-51442, demonstrated extensive sterilization of male Japanese beetles at 1% dosage levels.

At Moorestown the presence of a male attractant in female Japanese beetles was determined by purifying gases given off in a closed chamber by female Japanese beetles.

A grid trap design was used at Moorestown to determine the behavior of Japanese beetle captures in relation to foliage. Numbers of beetles captured were increased when traps were close to foliage or vegetation.

Large scale field tests of Japanese beetle attractants in Georgia, Indiana, Nantucket Island, Mass., and New Jersey indicated that phenyl ethyl butyrate-eugenol 9:1 was generally more attractive to Japanese beetles than either geraniol-eugenol 9:1 or anethole-eugenol 9:1. In a few instances geraniol-eugenol, a more effective attractant for beetles than anethole-eugenol, captured as many beetles as phenyl ethyl-eugenol.

In Japanese beetle trap studies made on Nantucket Island in 1965 bumble bees were attracted to yellow bait traps containing anethole-eugenol in large numbers. Subsequent studies of color and lures showed that the principal attractant of these traps for bumble bees was the yellow color. White traps also attract bumble bees. Different aromatics used to attract Japanese beetles vary in their attraction of bumble bees. Bumble bees are highly attracted to anethole-eugenol but phenyl ethyl butyrate-eugenol, a better attractant for Japanese beetles, has a low attractancy for bumble bees. There was no difference in Japanese beetle catch between yellow or green traps.

About 3,000 acres on Nantucket Island were trapped to reduce Japanese beetle populations during 1965 and 1966. Twenty percent less beetles were captured in the standard blocks in 1966 than during 1965. In all traps the percent reduction was 40%. Degree of control contributed by the traps could not be fully evaluated because of varying climatic conditions in 1964 and 1965 when beetles were laying eggs. Rainfall was greater in the 1964 season. The large-scale block tests captured 12,272 beetles during 1966.

At Moorestown, N.J., a series of lures prepared by the Pesticide Chemicals Research Branch were paired with anethole-eugenol 9:1 in olfactometer and

field tests. ENT 23985-b dissolved in methylene chloride was ranked 1,940 compared to 100 for the standard. Another outstanding attractant was ENT 19663 plus eugenol which ranked 946. Six others ranked 514 to 348 in descending order when eugenol was added. In the field, ENT 21681, 33048a, and 7031 with eugenol were most attractive. Odors from ENT 7031 and 1854 were objectionable to persons living in the test area.

A satisfactory method for rapidly marking Japanese beetles used in recovery studies was developed at Moorestown. This method involved tumbling beetles in a 2-1/2-gallon metal can that contains Day Glo(R) fluorescent dust that is distinguishable in ultraviolet light. Pigments trapped in the ventral thoracic area remain visible throughout the life span of the beetles. Colors tested included: Arc yellow, fire orange, horizon blue, aurora pink, signal green, and saturn yellow. Arc yellow was readily distinguishable from the other pigments tested, but 4 of the pigments, fire orange, aurora pink, arc yellow, and signal green (or saturn yellow) are considered separatable when used in the field at the same time.

7. European Chafer. At Geneva, research under cooperative agreement with the New York Agricultural Experiment Station demonstrated that gamma radiation in excess of 5,000 r would reduce longevity when applied to chafer larvae. Grubs collected in the spring were more tolerant to radiation than those collected in the fall.

F. Evaluation of Equipment for Insect Detection and Control

1. Japanese Beetle. On Nantucket Island there were no significant differences in the numbers of Japanese beetles captured in the Ellisco(R), Metzger funnel, and PPC Scout traps. An experimental plastic trap developed by PPC personnel was less efficient. Bottles containing the attractant blew out and the cups used to hold the beetles captured became waterlogged, which reduced the number of beetles taken in these traps significantly.

2. European Chafer. At Geneva, N.Y., blacklight and chemical traps located 5 feet above ground level under the canopy of trees were more effective for capturing European chafer than those placed in the top of trees.

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